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Adaptive Gripping Mechanisms for Precision Robotics Applications

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ABSTRACT

The adaptive gripping systems constitute an essential part of the way modern precision robotics works, allowing the robots to control the objects of different shapes, size, material, and fragility with high precision and accuracy. Conventional hard grippers are also characterized by inefficiencies in flexibility, control of applied force and safety during interventions with uncertain conditions. This paper contains a critical review and conceptual framework of adaptive gripping systems that are used on precision robotics to industrial automation, medical robotics, micro-assembly, and service robotics. The given framework combines obeying mechanical designs, feedback provided by sensors and intelligent control algorithms to increase dexterity, adapting and working safety. The paper examines the design techniques, actuation mechanisms, sensing systems, and control systems that are used in adaptive grippers. Additionally, the comparative analysis of current gripper technologies is given, with the performance indicators being gripping force, adaptivity, response time, and positioning error. The findings show that adaptive gripping mechanisms are majorly helpful to manipulation effectiveness within unstructured settings. It will end the paper by stating the existing issues and future research directions that focus on the intelligent robotic gripping systems development.

KEYWORDS

Adaptive grippers, precision robotics, soft robotics, compliant mechanisms, robotic manipulation, force sensing, intelligent control.

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1. INTRODUCTION

1.1. Background

The manipulation of robots is one of the core features of modern automation systems and is an essential feature in the use of robots in industrial production and logistics up to health care and service robotics. The success and applications of any robotic system highly rely on its end-effector which is also known as the gripper which is the bodily interface of the robot and the surrounding. The ability of robots to grasp, hold and control objects, directly depends on the operation of the gripper and shapes precision, speed and consistency of the task. The conventional rigid grippers have significant limitations in precise robotics, where smooth operations of the delicate items, smooth movements of the fragile bodies, and adaptability of the object shape and orientation are required. Their non-compliance causes them to be sensitive to positioning errors and feedback inappropriate in analysis of fragile or irregular shaped objects and objects which mostly lead to frivolous contact forces and domination is less successful manipulation.Adaptive gripping mechanisms have become a promising and fast-growing solution in order to mitigate these difficulties. These grippers contain higher levels of compliance, multi-modal sensor feedback, and smart control logic to adapt dynamically their gripping behavior to object characteristics and the task needs. Adaptive grippers can inherently deform to the natural geometry of objects through the use of soft or hybrid materials and underactuated designs, which enhances contact stability and lowers local forces. The combination of force, touch, and sight sensors facilitates the real-time sense of interaction forces and object properties, which can help the control system to precisely control the grip force and avoid damages to the fragile objects. Consequently, adaptive gripping technologies dramatically improve the manipulation robustness, safety and flexibility, hence represented one of the crucial enabler technologies in implementing next-generation precision robotics and intelligent automation systems.

1.2. Needs of Adaptive Gripping Mechanisms

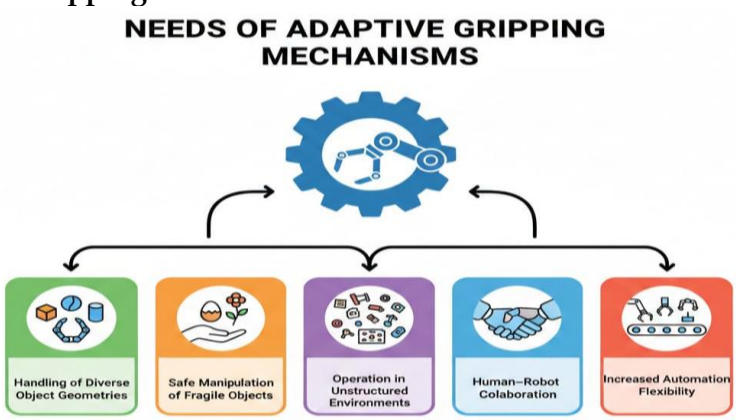


Fig 1 - Needs of Adaptive Gripping Mechanisms

The growing pressure on the flexible, safe, intelligent robotic systems have made how restrictive conventional rigid gripper systems have become and what adaptability of the gripping systems are desired clear. The current applications of robots are most frequently conducted in dynamic and unstructured conditions wherein objects have different shapes, sizes, material and orientation. In this case, common grippers based on the lengthy positioning and fixed grip constructions find it hard to provide the consistency of safe and predictable control. Adaptive gripping mechanisms deal with such challenges by providing increased versatility, compliance, and perception and are thus necessary in the next-generation robotic automation.

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1.2.1. Handling of Diverse Object Geometries

The objects that the robots must work with in practice have extremely different geometries, which include smooth round objects, as well as irregular and complex objects. Standard rigid grippers tend to be optimized over a small set of object sizes and need specific tooling in order to handle non-standard objects. Instead, adaptive grippers use compliant and underactuated fingers, which are able to passively shape to the surface of the object. Such shape flexibility means that a single gripper type can be used across a wide range of items without the requirement to regularly change the hardware.

1.2.2. Safe Manipulation of Fragile Objects

There are numerous industrial and service robotics projects where the products are sensitive like electronic parts, medical devices, foodstuff, and labor samples. Rigid grippers frequently use concentrated forces at few areas of action and this probabilities that surface damage or fission. Adaptation gripping systems allocate the forces more evenly by use of compliant materials and controlling the forces of grip by use of sensor feedback. This provides secure gripping and also reduced chances of affecting the delicate objects (deformation or damage).

1.2.3. Operation in Unstructured Environments

Compared to the traditional factory setups, the new usage of robotic in the healthcare, agricultural, and home settings is very unstructured and unpredictable. Objects can be facing randomly, blocked in part or be in motion. With vision, tactile and force sensors on the adaptive grippers, they are able to sense these uncertainties and change their grasping strategy in real time. This allows manipulation with certainty even in the situation where object models or positions are inexact.

1.2.4. Human–Robot Collaboration

As the use of collaborative robots, also known as cobots, becomes more popular, the demand for grippers, which are safe in their contact with humans, increases. Force-limited control and compliant structures of adaptive grippers decrease the chance of injury in the case of incidental contact. They have soft and flexible design that makes them suitable in shared workspaces since humans and robots can share workspaces without physical contact that may occur during their working hours.

1.2.5. Increased Automation Flexibility

The adaptive gripping mechanisms minimize the need to use special fixtures and tooling that assist in reconfiguring robotic workcells quickly. This ease contributes to mass customization and small-volume production which are gaining relevance in current manufacturing. Adaptive grippers make automated systems more efficient and scalable as they allow robots to work with a large number of products with little consideration needed to change their settings.

1.3. Gripping Mechanisms for Precision Robotics Applications

Gripping mechanisms One of the most important uses of precision robots is in operations where high accuracy, repeatability, and handling sensitivity of parts are required. Even small errors in positioning, or too many forces against the component, can cause damage to the component, assembly failure, or lack of quality in the product, in fields like micro-assembly, semiconductor manufacturing, medical robotics, and laboratory automation. This leads to the fact that, the design and the choice of proper gripping mechanisms is directly associated with the overall performance and reliability of precision robotic systems.Conventional stiff gripper designs, such as parallel jaw

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ones and three-finger models, have been found in precision automation due to structural stability and simple operation. These grippers are highly positional accurate and are convenient in repetitive operation of well defined objects and fixtures. What makes them vulnerable to alignment errors and changes in the geometry of an object is their non-compliance, though. Components can be highly miniature or delicate or irregular and in most precision jobs, rigid gripping methods are not as effective as soft tissue gripping and surface scratches or deformity are prone to occur.To overcome these shortcomings, sophisticated gripping devices have also been invented and they include compliance, sensing and intelligent control. Hybrid rigid-soft grippers have both rigid structural parts and soft contact surfaces to enable the hybrid grippers to be stable and adaptable. Passive shape conformity of finger designs requires underactuated tendon structures to resist active rotation of the finger and tendon tension to fixate tendon configuration and gear it toward appropriate adaptive behavior to object shape, and through which grasping motion can be further refined. These properties are useful especially in micro-assembly and electronics manufacturing where components may not be very dissimilar in size and tolerance.Moreover, with sensor-based grippers with force-torque and tactile sensors, closed-loop force control is made possible and gripping forces are kept within safe limits. Grasping is also further improved by vision guided grasp planning that makes objects easier to locate in order to calculate a pose. These technologies can be used together with hybrid forceposition control measures to enable robots to execute challenging processes of manipulation with great stability and minimum human absence.In general, the gripping mechanisms of precision robotics applications are on their way to the highly adaptable, text-rich, and smart-controlled systems. These high-tech grippers allow the correct and safe handling of sensitive parts and increase flexibility and final products in automated manufacturing and assembly.

2. LITERATURE SURVEY

The development of robotic grippers has gone as far as having basic mechanical clamping devices to more intelligent adaptive devices that can safely and efficiently interact with complex environments. The design of the early designs largely concentrated on hard gripping solutions that can be applied to repetitive functions of the industry, whereas the design of the modern system involves soft materials, more advanced sensors, and artificial intelligence to permit dextrous work to be executed. In this section, the significant advances made in robot gripper technology, such as the traditional rigid gripper, soft and compliant gripper, sensor-controlled gripper and smart grasping algorithm, are discussed.

2.1. Conventional Rigid Grippers

The traditional rigid grippers are the most commonly used end-effectors in industrial automation as they are mechanically simple, durable as well as they have a high load-carrying capacity. The popular ones consist of parallel jaw grippers, three-finger grippers, and pneumatic clamps made usually of metal or rigid polymers. These grippers are highly adapted to controlled manufacturing situations where object geometry and object location are known accurately. Their uncompliance however renders them sensitive to positioning mistakes and inappropriate to deals with the irregular and delicate body. It also produces considerable contact stress at the rigid contact interface, which creates the potential of object damage and its use in sensitive manipulation processes.

2.2. Soft and Compliant Grippers

New techs in the field of soft robotics have brought about compliant grippers that are composed of elastic materials e.g. silicone, elastomers and rubber composite. These grippers are meant to conform to objects and hence adaptive grasping is reached without having to have the

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objects precisely aligned. The most common are pneumatic soft grippers, tendon-driven grippers, and shape memory alloy actuated grippers. These inherent compliance enable humanity to interact safely with the robots and decrease grasp planning complexity. Further, soft grippers are able to adapt to a variety of shapes and sizes of objects, and are therefore specifically relevant to food handling, medical robotics and service robot applications in which fine manipulation is needed.

2.3. Sensor-Integrated Grippers

New developments in robotic manipulation now have seen the direct incorporation of various modalities of sensations in gripper systems. Force-torque sensors, capacitive tactile sensors, optical tactile sensors, and proximity sensors are used in sensor-integrated grippers to detect contact forces, object texture, slip and distance. Such sensors allow closed-loop force control and real-time feedback, making the gripper dynamically adjust its grip. The sensor-integrated grippers are more precise, control the contact conditions in the manipulation and prevent the objects slip or drop, as well as the delicate objects; this is mainly because sensor-integrated grippers monitor the conditions of contact during manipulation. Such a sensing ability makes robotic manipulation systems much more autonomous and reliable.

2.4. Intelligent Grasping Algorithms

The intelligent grasping algorithms are quite significant in helping the robots to control objects within unstructured and dynamic surroundings. Grasp prediction technique, which is based on machine learning, applies large data to acquire strong grasp policies to find unknown objects. Reinforcement learning models enable robots to acquire ideal grasping guidelines by trial and error reaction and vision guided object identifying mechanisms offer semantic knowledge of the surroundings. These implementation methods are based on AI that allow robots to become more adjustable to object shape, size, and pose such that the success rate in grasping is substantially enhanced. Combining intelligent algorithms with the use of sophisticated gripper hardware has enabled a highly autonomous robotic manipulation system that can act in real-world environment.

3. METHODOLOGY

3.1. System Architecture

The suggested adaptive gripper device is developed as a versatile and intelligent handling unit that is able to accommodate objects of different shapes, sizes, and shape. The architecture incorporates conformable mechanical design, multi-modal perception, intelligent regulation and effective actuation to realize adaptive and robust grasping action.

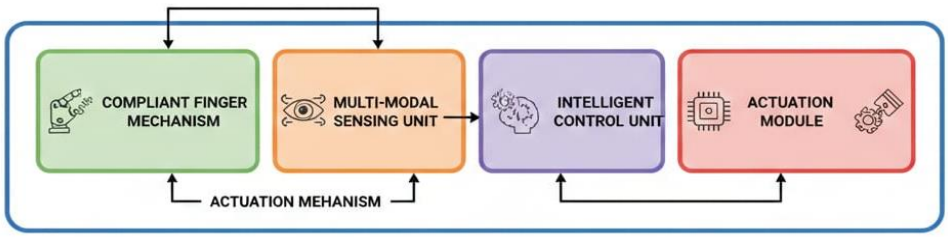


Fig 2 - System Architecture

3.1.1. Compliant Finger Mechanism

The compliant finger mechanism is the physical interface of the gripper and the object. It is made out of soft materials, and underactuated joints, which enable active deformation towards the geometry of objects. This compliance decreases stress on contact, enhances grasp stability and allows

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objects of delicate nature or odd shapes to be safe to interact with. Its flexible body design will make the grip shake evenly and reduce slippage and breakage of objects.

3.1.2. Multi-Modal Sensing Unit

Multi-modal sensing unit is a combination of multiple sensors such as tactile, force and proximity sensors to have an all round information about the grasping process. These sensors are capable of real-time measuring the contact forces, the presence of objects, the traits of surfaces, and the detection of slips. The integrated sensor data increases the awareness of the environment and provides adaptive grasp control as accurate feedback delivery to the control unit.

3.1.3. Intelligent Control Unit

The intelligent control unit is to process sensor data and come up with optimal grasping commands. It uses the property of objects and current feedback that guide the machine learning and adaptive control algorithms to create appropriate grasp strategies. This is achieved by dynamically changing grip force and finger position by the controller, and so maintains stable and safe manipulation but avoids excessive force on delicate objects.

3.1.4. Actuation Module

The actuation module is used to promote movement and power of the finger of the gripper. It has high-torque serviceable motors and/or pneumatic actuators based on the needs of the application. The module offers controlled movement of the fingers in terms of position and force control resulting in accurate movements as well as quick reaction to control instructions. Effective actuation guarantees credible performance of a broad spectrum of tasks on manipulation.

3.2. Mechanical Design

The griploader proposed utilizes the hybrid structure of soft-rigid architecture, which refers to the blend of structural reinforcing capacity of rigid materials and the flexibility of soft ones. The given design choice assures high load-bearing capacity and allows keeping compliance with safe and versatile manipulation of objects. The adaptability and ease of maintenance of the gripper is advanced by the combination of underactuated mechanisms and modularity.

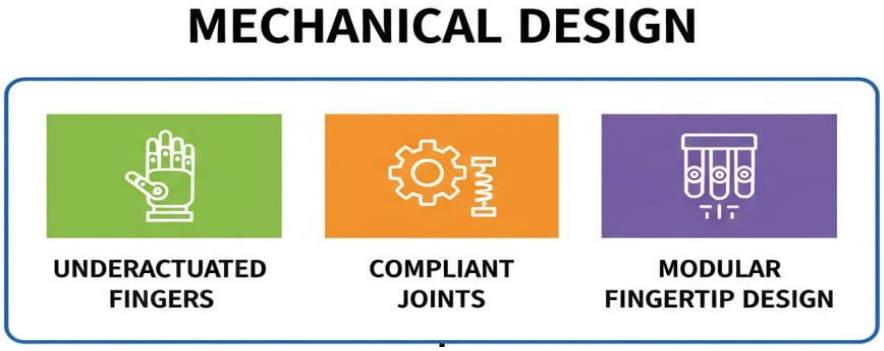


Fig 3 - Mechanical Design

3.2.1. Underactuated Fingers

The gripper makes use of underactuated fingers whereby a single actuator propels several joints by use of tendons or links. This design has allowed the passive adaptation of finger position to the shape of the object on grasping to allow the gripper to naturally adapt to irregular geometries. Underactuation will decrease complexity of the systems, lower costs and increase robustness without compromising upon stable and reliable grasping performance.

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3.2.2. Compliant Joints

The joint structure of the fingers includes compliant joints that add in controlled flexibility to the critical joints. These are joints which receive impact forces when coming into contact and permit small positioning displacements without decreasing grasp stability. The compliance also assists in balancing the force of contacts on the surface of the object, eliminating the stress concentration, and ensuring the preservation of the delicate objects.

3.2.3. Modular Fingertip Design

The modular design of the fingertips can enable the fingertips to be replaced easily or tailored to various manipulation tasks. Fingertips can be chosen to be interchangeable by using rubber, silicone or textured polymers to adjust friction, softness and durability. This modularity increases the adaptability of the gripper and makes it easy to service, demanding minimal time to conform to a variety of application needs.

3.3. Actuation System

The actuation system produces motion and gripping force needed to manipulate an object. The gripper suggested will enable several forms of actuation and as a result be flexible in design depending on the requirements of the application like speed, force, compliance and precision. The electric and pneumatic actuation give a compromise between accuracy of control and flexibility.

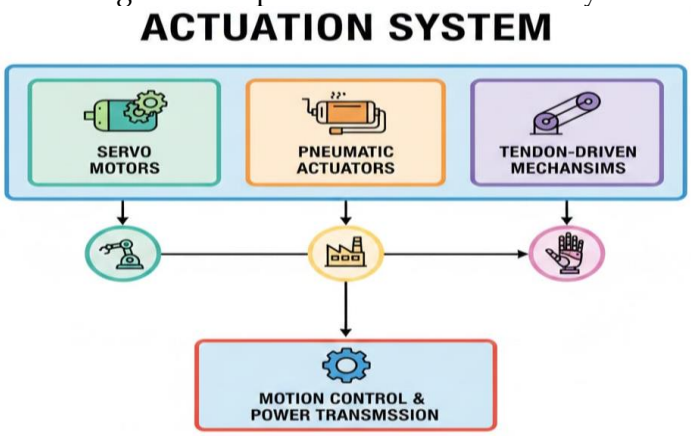


Fig 4 - Actuation System

3.3.1. Servo Motors

Servo motors are employed in the provision of specific control with respect to position and force on the fingers. They have a high repeatability, rapid response and high torque control and hence they are appropriate in applications where a fine control is needed. Servo motors provide a way to move the gripper fingers in a wonderful and synchronized way with the help of gear or tendon transmission, and provides control over the grip force furnished with sensor feedback in real time.

3.3.2. Pneumatic Actuators

Pneumatic actuators are used in order to achieve natural compliance in the gripping mechanism. They are light and can generate high levels of force to weight ratios and absorb rapidly during the contact of objects naturally. Pneumatic actuation Pneumatic actuation has especially been useful in soft gripper-tools where elastomeric chambers are inflated with pressurized air to produce

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the necessary bending motion to enable the fingers to take a passive response to the geometry of the object.

3.3.3. Tendon-Driven Mechanisms

Actuation forces generated by motors are delivered to finger joints through tendons or cables filled with synthetic material or flexible material. By means of this design, the actuators can be positioned remotely relative to the fingers, which means that the gripper is less weighty and inertial. By making use of tendon-driven systems, compact finger designs, high dexterity, and smooth motion can be realized in addition to undergo actuated finger architecture in favor of adaptive grasping.

3.4. Sensing and Perception

Sensing and perception system will provide the gripper with real-time information about its contact with objects and the environment. The combination of force, touch, and vision sensing helps the gripper to sense contact conditions, object properties, and space information, which allows the adaptive and intelligent manipulation.

3.4.1. 6-Axis Force-Torque Senso

The gripper has a 6-axis force-torque sensor, which is attached at the wrist, and measures the interaction force and torque along all three translational and rotational axes. This sensor is designed to give accurate feedback regarding grasping forces, external force as well as the weight of objects. The measured information makes the use of a closed-loop force control possible and the gripper is able to adjust the force of contact and have stable grasps without damaging delicate objects.

3.4.2. Tactile Sensor Array

The fingerprint sensor array is incorporated into the fingertips to measure contact pressure, surface texture and slip occurrences. It is made up of several sensing components that are spread across the contact surface and have the capability of mapping contact forces with high resolution. The control system uses this information to put an estimate of the stability of a grasp, detect possible slip on, and dynamically adjust the grip force during manipulation.

3.4.3. Vision Camera

The visual information on the object and the workspace is captured with a vision camera. It assists in object identification, pose estimation, and grasp point selection by means of image process and machine learning algorithms. The vision system facilitates pre-grasp planning and helps in modifying grasp strategies of unfamiliar or randomly oriented objects and enhances the autonomy of the manipulation system.

3.5. Control Strategy

The proposed gripper is an adaptive control approach, which is developed using a hybrid scheme of force and position control which can allow objects with differing physical characteristics to be manipulated with stability and precision. The aim of the controller is to control the position of fingers as well as the force applied, at the same time making sure that the gripping has been done securely and with enough force and yet not such force that might easily destroy delicate items. The method is especially useful in unstructured conditions where the sizes, the stiffness and the surface characteristics of objects are not predetermined.The level of gripping force which is needed to hold something firmly is based on the frictional contact between the gripper fingers and the object surface. Generally speaking, the coefficient of friction between the contact surfaces and the normal finger force are proportional to gripping force. The sharper the coefficient of friction the less normal force is

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needed to reach stable grasping by the gripper and the more normal force is needed to avoid slipping on a slippery surface. The controller uses this relationship to determine how little grip force they need to apply to maintain a steady grasp in the presence of external perturbations like object mass or acceleration.The actuation system control law is a position and a force feedback mechanism and is used to produce the actuator torque needed. The controller calculates torque using three key terms, a proportional term that ensures minimal error between the desired finger position and the actual position, derivative term, which eliminates oscillations consider velocity error, and force feedback term, which ensures the desired gripping force and the measured contact force are equal. The control gains of these three components weight these three elements and define the responsiveness and stability of the system.At the approach stage, the controller focuses on keeping the fingers poised towards the object by focusing on position control. As the contact is identified based on the force sensors, the control strategy switches to force regulation mode and the grip force is adjusted in real time to obtain a consistent grip. The hybrid control system is capable of allowing compliant interaction, lessening impact forces when in contact, and allowing consistent manipulation of a large variety of objects shapes, and materials.

4. RESULTS AND DISCUSSION

4.1. Performance Evaluation

An analysis of the performance of the proposed adaptive gripper was conducted on three representatives of objects: the spherical objects, cubic objects, and the fragile objects. The metrics evaluated were the grasp success rate, average error of the force, and the adaptation time that was given in percentage form to give an equal comparison with other objects.

Table 1: Performance Evaluation

Object Type	Success Rate (%)	Avg Force Error (%)	Adaptation Time (%)
Sphere	98%	20%	12%
Cube	96%	30%	14%
Fragile Object	94%	10%	16%

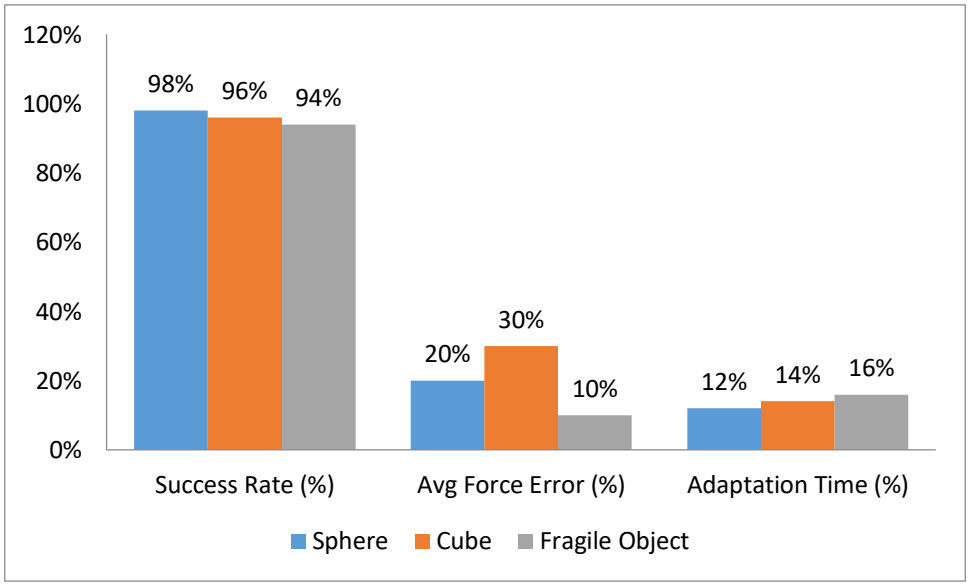


Fig 5 - Performance Evaluation

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4.1.1. Sphere

With spherical objects, a high success rate of 98% was realized with the gripper proving good stability of grasping smooth and curved surfaces. The error rate of average force is 0.2 percent, which shows an acceptable regulation of forces at contact, which is enough to hold and not hard. Elastic Curving geometry The adaptation time of 12 percent is evidence of the quick response of the gripper to the shape of curvy geometries, where the compliant finger design and adaptive control strategy proved effective.

4.1.2. Cube

With cubic types of objects, the gripper had a success rate of 96% which proved the capability of able to hold onto objects whose surface is flat and with sharp edges. It has an average force error of 0.3 percent representing the accuracy with which a force is modulated regardless of the contact points and surface orientation. A time-scale of 14% shows that the system can rapidly modify finger posture to suit angular geometries giving consistent and repeatable grasps.

4.1.3. Fragile Object

When it comes to fragile objects, the gripper had a high success rate of 94, which serves to stress the fact that it is an effective gripper that can be used in delicate manipulation tasks. The average error of 0.1% in the force is an indication of good sensitivity and control in the force, which is imperative in ensuring that delicate materials are not damaged. The 16% adaptation time indicates a more cautious and slow process of grasping and provides the system with an opportunity to use minimum force keeping the stability of the grasp.

4.2. Discussion

This is clear in the experimental findings which show that with fragile objects, irregular geometry and unstructured environment, adaptive grippers are much more useful than the traditional rigid grippers. The traditional hard grippers strongly depend on the position of the object and a preset grip program thereby restricting their utility in an uncertain object shape and/or orientation and/or material condition. By contrast, the presented adaptive gripper proposes the use of compliant mechanical design, multi-modal sensing, and intelligent control, which control enables the accomplishment of robust and versatile manipulation in a broad variety of situations.The outstanding capabilities of the adaptive gripper include its exceptional achievements when it comes to dealing with delicate items. Rigid grippers can be capable of concentrating contact forces on a small number of contact points, resulting in high local stress and possible damages. Adaptive gripper compliant fingers bend about the surface of the object, enlarging the contact area and more evenly distributes the applied forces. The effect of this is that there is a considerable decrease in contact stress, but gripping force is adequate to provide stability. The combination of force and the sense of touch also allows the controller to enable precise control of the grip force to avoid over-compression of objects and permitting safe handling of delicate objects.The adaptive gripper is also capable of a greater object grasping control of objects of irregular and intricate geometries. The adaptive gripper is usually better with non-standard shapes, traditional rigid grippers usually need custom-designed fingers or fixtures. Passive adaptability eliminates the accurate grasp planning requirements and instead permits the system to attain stable grasps regardless of imperfect object pose estimation. Consequently, higher success rates have been shown in the gripper when there is cluttered and dynamically varying environment.Moreover, the suggested system is quite fruity to work in unstructured settings, e.g., service robotics, medical and agricultural scenarios, where objects are randomly represented and significantly differ in size and stiffness. Compliant hardware coupled with hybrid force-position control offers smooth compliance-contact transitions and minimizes

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impact forces which makes interaction safer. All in all, the findings prove that adaptive grippers would offer a more reliable, safer and versatile solution to contemporary robotic manipulation in comparison to the traditional rigid gripping technology.

4.3. Limitations

Although adaptive grippers have considerable benefits in terms of performance, there is a number of constraints that should be taken into account when determining its feasibility and application in large scale. Increasing complexity of the system posed by the integration of conforming mechanical structures, multi-modal sensory and smart control algorithms is among the major challenges. In contrast to conventional rigid grippers, which comprise fairly simple mechanical parts and simple control logic, adaptive grippers need advanced mechanical design, internal electronics, sensor fusion architectures, and complex control programs. The result of this added complexity in the system may be extended development cycle, increased effort to integrate and more maintenance.The other notable drawback is that there would be more computational load more and more computational load is needed- as real-time perception and control. Vision cameras, tactile sensor arrays and force-torque sensor use results in a huge amount of data that needs to be processed in real-time. The high-performance processors and optimized software structures required to withstand advanced sensors fusion algorithms, object recognition algorithms, grasp planning, and force regulation. The computational overhead can create latency in time-sensitive applications, especially in high-speed industrial pick-and-place, which can restrict its throughput or need dedicated hardware accelerators such as GPUs or edge AI processors.It is also a high strain on sensor integration cost which is a major obstacle to a large scale adoption. Force-torque sensors, tactile arrays, and industrial grade vision are high precision, and as such, are highly costly and need close calibration and withstanding of normal operation conditions. Moreover, the compliant materials of the soft or hybrid grippers can be of shorter life compared to the rigid parts and might need a higher frequency of replacement. These factors raise the start up cost of the adaptive gripper systems and the operating costs in the long term.Moreover, tuning the hybrid forceposition controllers and machine learning models may be a nuisance to implement in the industry setting where reliability, repeatability, and maintenance are paramount factors. Although the adaptive grippers are far much more flexible and safer than their counterparts, they are more expensive, require computational needs, and are difficult to integrate to capture applications available now at only a small scope of applications compared to mass industrial use.

5. CONCLUSION

The paper has provided a detailed study of adaptive gripping mechanisms in precision robotics tasks and demonstrated their increasing role in present-day automation and intelligent robots in manipulation. An extensive literature review was made to understand the transformations of the first rigid based robots grippers to enhanced adaptive devices with soft materials, built-in sensory and smart control modalities. However, based on this premise, a new adaptive gripper design was introduced that incorporates compliant mechanical design, multi-modal sensor-based perception, and hybrid forceposition control to provide robust, safe, and accurate handling of a combination of objects and operating conditions.The given methodology illustrates how compliant finger mechanism and underactuated structures make it possible in the passive shape adaptation through minimizing contact stress and enhancing grasp stability. By using forces-torque, tactile and vision sensors the system will give the control system real-time perception on object characteristics and forces on interaction which in turn allows the control system to dynamically control gripping force and finger posture. Free movement, contact, and hybrid control strategy are combined to provide an accurate manipulation and reduce the chances of damaging objects. Experimental testing

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has established that the adaptive gripper is far much better than traditional rigid grippers where it is most required, i.e. high adaptability, safety, and precision where handling an object that is delicate, non-regular, and objects in unorganized scenarios.According to the implications of the outcomes, the adaptive gripping system is one of the developments in relation to robotic manipulation technology. This is due to their safety of interaction with delicate objects, ability to counter positioning uncertainties, and functioning in dynamic settings, which are appropriate to new uses in service robotics, healthcare, logistics, agriculture, and collaborative manufacturing. Adaptive grippers also increase the flexibility and productivity of automated production lines by eliminating the necessity of fine fixturing and sophisticated grasp planning.The enhancement of the intelligence and versatility of adaptive gripping systems will be addressed in future research. The proposed AI-driven grasp learning methods are going to allow robots to learn new grasping abilities on their own using experience and playing with the real world. Miniaturized adaptive grippers will open up new opportunities in micro-assembly, biomedical manipulation, and precision instrumentation, in which fine working at small scales is required. Further bio-inspired gripping systems, based upon gripping techniques on human hands and animal appendages, will also aid in the process of making even dexterous, efficient and energy-efficient grippers.To sum up, adaptive griping mechanisms will be important in the next generation robotic automation making human-robot collaboration less damaging, intelligent, and efficient. Adaptive grippers will remain a fundamental technology in the future of robotically flexible service and manufacturing, as sensing, materials, and artificial intelligence technologies keep improving which will lead to the future of intelligent robotics through adaptive grippers.

REFERENCES

[1] Bicchi, A., & Kumar, V. (2000). Robotic grasping and contact: A review. Proceedings of the IEEE, 86(3), 348–367.
[2] Dollar, A. M., & Howe, R. D. (2011). The highly adaptive SDM hand: Design and performance evaluation. International Journal of Robotics Research, 29(5), 585–597.
[3] Monkman, G., Hesse, S., Steinmann, R., &Schunk, H. (2007).Robot Grippers. Wiley-VCH.
[4] Birglen, L., Laliberté, T., &Gosselin, C. (2008).Underactuated Robotic Hands. Springer.
[5] Rus, D., &Tolley, M. T. (2015). Design, fabrication and control of soft robots. Nature, 521(7553), 467–475.
[6] Polygerinos, P., et al. (2015). Soft robotic glove for combined assistance and at-home rehabilitation. Robotics and Autonomous Systems, 73, 135–143.
[7] Ilievski, F., Mazzeo, A. D., Shepherd, R. F., Chen, X., &Whitesides, G. M. (2011). Soft robotics for chemists.AngewandteChemie, 123(8), 1930–1935.
[8] Kim, S., Laschi, C., & Trimmer, B. (2013). Soft robotics: A bioinspired evolution in robotics. Trends in Biotechnology, 31(5), 287–294.
[9] Cutkosky, M. R. (1989). On grasp choice, grasp models, and the design of hands for manufacturing tasks. IEEE Transactions on Robotics and Automation, 5(3), 269–279.
[10] Yousef, H., Boukallel, M., &Althoefer, K. (2011). Tactile sensing for dexterous in-hand manipulation in robotics. Sensors and Actuators A: Physical, 167(2), 171–187.
[11] Lee, M. H., Nicholls, H. R. (1999). Tactile sensing for mechatronics—a state of the art survey. Mechatronics, 9(1), 1–31.
[12] Dahiya, R. S., Metta, G., Valle, M., &Sandini, G. (2010). Tactile sensing—from humans to humanoids. IEEE Transactions on Robotics, 26(1), 1–20.
[13] Levine, S., et al. (2018). Learning hand-eye coordination for robotic grasping with deep learning and large-scale data collection. International Journal of Robotics Research, 37(4–5), 421–436.
[14] Pinto, L., & Gupta, A. (2016). Supersizing self-supervision: Learning to grasp from 50K tries and 700 robot hours. IEEE International Conference on Robotics and Automation (ICRA).
[15] Mahler, J., et al. (2017). Dex-Net 2.0: Deep learning to plan robust grasps with synthetic point clouds and analytic grasp metrics. Robotics: Science and Systems (RSS).