

ADAPTABLE MULTIFUNCTION ROBOTIC HANDS

FIELD OF THE INVENTION

5 The present invention relates to an apparatus and method for handling objects using a set of Multifunction Robotic hands that are interconnected, with each finger unit designed as an interchangeable tool that is capable of handling and executing specific tasks. The Robotic hands are operated using computer control systems with built-in Artificial Intelligence enabling the apparatus to learn and improve upon the process of executing

10 repeated tasks. The present invention, more specifically relates to a system and method to manipulate the finger units and palms of the Multifunction Robotic hands to perform delicate tasks such as opening container lids or caps, peeling the top cover of the contact lens package, picking up and positioning the ophthalmic or contact lens onto a pedestal for the imaging system to inspect and determine the characteristics of the lens and

15 unloading and sorting the inspected lens based on the characterized result. With additional options to Clean the lens containers with hot or cold deionised air, brushing the object or its container, dispensing saline liquid or other types of solutions at controlled speed, the Robotic hands provides a versatile system for deployment in a typical quality control process for the ophthalmic lens manufacturing industry.

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BACKGROUND OF THE INVENTION

Some automated tasks, especially those in which there are interactions between delicate and sensitive objects, require the collaborative work of multiple finger units in a Robotic

hand equipped with end-effector grippers. With flexible degrees of movements and built-in features for cleaning, pickup and placement of objects, Liquid dispensing, Gripping and rotating and sterilising features the Robotic hands are specially suited for operating in environments not suitable for deployment of humans for performing various tasks.

5 Most of the current disclosed art attempting such tasks require multiple stages of manual inspection or human intervention and the use of multiple mechanical manipulators to perform the task with a high possibility of errors being introduced during the process. Prior art limitations include dedicated manipulators mounted on separate platforms, time consuming reconfiguration process before they are deployed in manufacturing or quality
10 control process.

Humanoid robots may be preferred when direct interaction is required with devices or systems that are specifically made for human interaction with capabilities to communicate in a local or common spoken language. Where audio commands and understanding audio instructions are not required, humanoids are an overkill and also occupy a significant
15 amount of space. Moreover if physical movements of the Robots to multiple locations is not required, humanoids are not preferred due to space constraints and safety issues involved.

SUMMARY

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The implementation of the multifunction Robotic hands is an important step towards a space saving and efficient system for handling objects such as a soft contact lens or ophthalmic lens. In this invention the interest is to switch from manual manipulation of manufactured objects with non-dexterous grippers to high-dexterity Robotic hand

manipulation, where the degree of dexterity is selected according to the kind of task to be performed. In particular, the design of a hand for a set of tasks performed during quality control management is explored by designing two Robotic hands with at least five finger units for inspecting contact lenses with the aid of an intelligent AI based imaging system and subsequently sorting them according to their characterized categories to preassigned bottles or containers.

In this invention, a pair of highly dexterous multi-fingered Robotic hands is proposed in cooperation with an imaging system, that is able to perform the task of unloading a contact lens suspended in a saline solution in a blister package, to perform quality inspection of the contact lens, after gently peeling off the foil covering the contact lens holder or blister pack and subsequently sorting the lens into different containers based on the characteristics determined by the imaging system. Each finger unit in the pair of Robotic hands, is dedicated to at least a single task that includes but not limited to peeling the cover foil using a motor, unloading the contact lens from the lens holder to the inspection station, emptying and cleaning the contents of the lens holder, dispensing saline or other liquids (when required) and unloading and sorting the inspected lens and additional tools mounted in the palm area of the Robotic hands for loosening or tightening a container cap, a miniature camera for fine alignment of the object or the tools and a pedestal to position the object for inspection.

According to the first aspect of the invention, the Multifunction Robotic hand assembly includes a base structure connected to the hand structure mounted with at least five fingers. The fingers are operatively connected to the base structure electrically,

pneumatically and liquid dispensing tubes in a known combination to aid interchangeability of Robotic hands for performing different tasks.

Another aspect of the invention is directed to a pair of Multifunction Robotic hands
5 including a finger unit combining the thumb and the index finger to grasp small objects
such as a Contact lens blister package to enable another Robotic hand mounted with a
Rotary motor, to engage the shaft of the motor with the edge of the blister foil covering
the package and to peel off the foil using Rotary motion. Each of these Robotic fingers
are controlled by a control system that networks to an imaging system to aid in detecting,
10 locating and moving the object to be inspected by an imaging system. The details of the
imaging system and its related illumination module and control system is not discussed
as it is outside the scope of this invention.

Another aspect of the invention is directed to the Multifunction Robotic right hand that
15 includes a finger suitably integrated with an anti-static suction pad to pick up the contact
lens from a lens holder, move the contact lens to a platform or pedestal for inspection..
Another Robotic finger suitably integrated with an Air jet valve to blow hot or cold air or
any other type of non-toxic gas for the purpose of cleaning and sterilizing the object and
object holder. Another finger suitably integrated with non-static brush aids in cleaning
20 and a subsequent finger incorporated with a Solution dispenser performs the task of
dispensing liquid. Another finger is integrated with a miniature motor that works to
perform tasks involving Rotary movement as and when required. For eg: to engage the
motor shaft to the blister foil to peel it off from the lens holder or a container.

Another aspect of the invention is directed towards a set of Robotic hands that are interchangeable with every finger assigned to a particular task.

Another aspect of the invention is directed towards at least one finger of the Robotic hand
5 integrated with a motor with positional feedback via encoders, to enable a section of the finger, to be rotated by a specific angle for achieving multiple orientations.

Another aspect of the invention is directed towards at least one finger of the Robotic hand incorporated with antistatic pressure sensors to enable delicate and static sensitive objects
10 to be safely handled at different stages of the process flow.

Another aspect of the invention is directed towards motorized or pneumatic X-Y displacement mechanisms with built-in encoders, mounted on at least one finger of the Robotic hand to enable fine positioning of objects with positional feedback.
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Another aspect of the invention is directed to a Robotic apparatus that includes a Rotary motor with built-in encoders, suitably integrated into the palm of the Robotic hand combined with a gripping manipulator to enable loosening or tightening of nuts, bolts, caps and lids of containers.
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Another aspect of the invention is directed to the pair of Robotic hands, which are mounted with proximity sensors and suitably positioned infrared (IR) sensors for the purpose of collision avoidance when executing various tasks.

The invention enables the implementation of a Multifunction Robotic hands to manipulate objects with various degrees of movement with the added capability of easily interchanging the tasks of the individual fingers and hands without expensive and time consuming modifications to the setup to perform delicate tasks especially when the
5 workplaces are toxic, dirty, oily and sensitive to static charges.

Other manufacturing applications where the present invention may be deployed include Mobile phone glass inspection for defects, manufacturing of Coronary artery bypass grafting and Angioplasty accessories, in operating theatres during surgery, sorting and
10 binning in Warehousing and Postal Services.

Persons skilled in the art will appreciate that other arrangements of the invention are possible, and consequently the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.
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BRIEF DESCRIPTION OF DRAWINGS

The above features and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken
20 in connection with the accompanying drawings, in which:

FIG. 1 shows a configuration of the present invention according to a first embodiment.

Fig 2 is an isometric view of a typical empty contact lens blister pack.

Fig 3 is an isometric view of a hermetically sealed blister package containing a contact lens with the Robotic Right hand motor shaft engaged with the edge of the blister foil.

- 5 **Fig 4** is an isometric view of a blister package with its blister foil peeled exposing the contact lens.

Fig 5 is a perspective view of the Multifunction Robotic Right back hand according to the first embodiment.

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Fig 5a is another perspective view of the Multifunction Robotic Right Front hand (showing the palm) according to the first embodiment.

- 15 **Fig 6** is a side view of the Multifunction Robotic Right hand index finger unit according to the first embodiment.

Fig 7 is a side view of the Multifunction Robotic Right hand middle finger unit according to the first embodiment.

- 20 **Fig 8** is a side view of the Multifunction Robotic Right Ring finger unit according to the first embodiment.

Fig 9 is a side view of the Multifunction Robotic Right hand little finger unit according to the first embodiment.

Fig 10 is a perspective view of the Multifunction Robotic Right hand according to the second embodiment.

- 5 **Fig 11** is another perspective view of the Multifunction Robotic left hand according to the first embodiment.

Fig 12 shows a flow diagram showing the steps during the process of contact lens inspection and characterization according to the first embodiment.

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Detailed Description of Drawings

Hereinafter, a Multifunction Robotic hands, interchangeable Robotic finger units and a Robotic device according to exemplary embodiments of the invention will be described referring to the accompanying drawings. It is important to note that the same reference
15 numerals are given to the same or like members and parts in the different drawings.

As shown in **FIG. 1**, the Multifunction Robotic Hands **20** and **40** according to the first embodiment includes five finger units in each hand. A miniature motor **25** is integrated
20 into the little finger unit of the Robotic Right hand **20** with interchangeable shafts **30**. The second Multifunction Robotic hand **40**, functions as a manipulator to locate and position objects under the imaging system **18** comprising a Camera **10**, optical lens **12** and illumination module **15**. The Robotic hands are designed to be quickly interchangeable through snap-on polarised connectors **42** as shown in **Fig 1** for the Robotic left hand **40**.

The dual Multifunction Robotic hands together with the imaging system operate in synchronization to perform complex tasks in different environments. Due to their hermetically sealed design, the Multifunction Robotic hands may be deployed in clean rooms, toxic, hot or humid workplaces, operating theatres for surgical procedures,
 5 humanoids, food packing industry, Pharmaceutical and Glass industries to name a few.

The system and method illustrated in **Fig 1** relates to peeling the blister foil **65** from the Contact lens holder **50** without any human interaction, wherein the Robotic left hand **40** is used for grasping the object (for eg: the Contact lens container **50**) and positioning it
 10 under the imaging system camera **10**. The imaging system **18** detects the edge of the blister foil **65** and communicates the location to the Robotic Right hand **20** which moves the Motor shaft **30** to engage the blister foil **65** of the blister pack **50** held by the Multifunction Robotic left hand **40**.

15 **Fig 2** is an empty blister shell **50** without a blister foil covering the package.

Fig 3 is an isometric view wherein the Motor shaft **30** of the motor **25** has engaged with the edge of blister foil **60** at the location **65**. As earlier explained the motor is suitably integrated to the little finger of the Multifunction Robotic Right hand and with the aid of
 20 the imaging system **18** in **Fig 1**, accurately engages with the blister foil edge **65**, before the shaft **30** in **Fig 3** is energised to rotate in the clockwise direction or the peeling direction while synchronously moving the Multifunction Robotic Right hand in the direction **28** and in the process peel the blister foil from the Top surface of the blister pack or Shell **50**.

Fig 4 shows how the process of peeling the blister foil that has been partially completed with the contact lens **70** exposed, with the motor **25** positioned at the opposite end of the blister pack. In the next step (not shown), the motor **25** continues to rotate the shaft **30**
 5 until the blister foil **60** is completely detached from the blister pack **50** and subsequently discarded.

Fig 5 and **5a** shows a perspective view of the Multifunction Robotic Right Hand from the back and front respectively according to the first embodiment of the present invention,
 10 and includes five finger hermetically sealed units, the thumb **80**, the first or index finger unit **83**, second or middle finger unit **90**, third or Ring finger unit **95** and the fourth or little finger unit **20**. A support section **98** drives the five finger units and interconnects to the external interfaces via drive section **22**. External interfaces may include a humanoid arm, or an automated manipulator to name a few. Commands received at the interface is
 15 subsequently communicated to the support section **98** to manipulate the five finger units and their respective features such as motors, air jets, brush, solution dispenser, X&Y displacement drives, Bottle openers and to monitor a host of sensors incorporated in the fingers to read pressure, temperature, positional data. Section **22** through a unique interlocking interface to the external control system, aids in channelling the pneumatics,
 20 electrical and bidirectional computer interface for communication of the Robotic Right hand. It is suitably designed for easy interchangeability, adaptability and scalability.

The five finger units in the first embodiment of the present invention are designed with specific features such as tactile sensors, Hall effect sensors, Pressure sensors and

temperature gauges to apply them to different tasks. The Robotic finger units are also modularly designed with standardised interface for mechanical, Electrical and Pneumatic control, to enable the Robotic hand to be quickly reconfigured for different applications.

5 According to the first embodiment of the present invention and referring to **Fig 5a**, the thumb **80** is designed with a rubber adapter **82** wherein the surface is rough but soft to enable it to grip objects. The Robotic Right hand index finger unit **83** in addition to the rubber gripper **84** and an opening **86** to dispense a solution through an electrically controlled valve (not shown) on one side, is also integrated with a brush **85 (Fig 5)** on the
10 other side, to aid in cleaning and brushing of an object. The middle finger unit **90** consists of a rubber gripper **87** and an opening **88** to blow clean and deionised air through an electrically controlled pneumatic valve (not shown) to enable cleaning and drying of an object. The Robotic Right hand ring finger unit **95** is integrated with a Suction cup **92** suitable for picking up objects from a predetermined location and placing them at multiple
15 locations. The little finger unit **20** is incorporated with a miniature motor **25** with an interchangeable shaft or tool **30** to perform multiple tasks. A rotary gripper **40** is integrated in the palm area of Robotic Right hand **98** that may be utilised to loosen or tighten screws, nuts and caps from bottles or any other task that requires Gripping and Rotational movement.

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Fig 6 is a side view of the Robotic Right hand index finger unit **83**. As illustrated, the tip of the index finger unit is incorporated with a Rubber pad **84** made from flexible resin, a small opening **86** for spraying a fine jet of solution through a tube **81** for cleaning purposes and a brush **85** for scrubbing the object. The jet is controlled by a computer triggered

valve (not shown). The fingertip of the index finger unit **83** is designed to be rotatable around the joint **82** along the axis **A1** to enable the brush **85** to be turned **180** degrees from its original position.

5 **Fig 7** is a side view of the Robotic Right hand middle finger unit **90**. As shown, the tip of the middle finger unit is also incorporated with Rubber pad **87** made from flexible resin and a small opening **88** connected to an air jet valve (not shown) through a pneumatic tube **96**. The air jet may be controlled to deliver deionised hot or cold air to the object for removing any static charge and to also clean and dry the object before the next process
10 step.

Fig 8 is a side view of the Robotic Right hand ring finger unit **95**. It is used to pick up an object using a suction pad **92** whenever an object needs to be moved to another location. For eg: The Ring finger unit **95** may pick up a contact lens **70** in **Fig 4** using the suction
15 cup **92** in **Fig 8** and place it on the pedestal **44** in **Fig 11** before the Robotic left hand in **Fig 11** position itself suitably under the imaging system **18** in **Fig 1** for contact lens inspection and subsequently presenting itself to the Robotic Right hand finger unit **95** in **Fig 8** for the contact lens **70** to be picked up from the pedestal **44** in **Fig 11** and placing it at another location such as a container or tray. The suction pressure is created at **92** in
20 **fig 8** through the tube **89** via a computer controlled valve (not shown).

In **Fig 9**, a side view of the Robotic Right hand little finger unit **20** shows a miniature motor **25** suitably integrated to the base. An interchangeable rotor or tool bit enables multiple tasks to be accomplished.

In a second embodiment of the present invention **Fig 5a** illustrates a configurable bottle opener **40** which is suitably integrated into the palm area of the Multifunction Robotic Right hand, that provides Rotary action in both clockwise and anti-clockwise direction, combined with force and Torque control to enable bottle caps to be loosened or tightened. The design of the bottle opener **40** is such that it caters to different and multiple forms of bottle cap profiles. The Bottle cap opening method is illustrated in **Fig 10** wherein the bottle cap **105** of bottle **104** is engaged with the Rotary fixture **40** in **Fig 5a** mounted on the Robotic right hand area **98**. This feature may be applied to any task that requires a rotary motion in combination with a gripper to hold and rotate the object. Other applications include, Nut or Bolt loosening or tightening..etc.

In **Fig 11** a third embodiment of the present invention is shown. **Fig 11** illustrates a configuration of the Multifunction Robotic left hand which is primarily used for gripping and positioning of objects as depicted by **40** in **Fig 1**. The palm is incorporated with an optional Camera **43** to enable fine alignment and tracking where required. It may also house a pedestal **44** (**Fig 11**) in the palm area to hold and present a contact lens placed by the suction cup **92** in **Fig 5a** of the Robotic Right hand Ring finger unit **95** in **fig 5a** , for the imaging system **18** in **Fig 1** to inspect it. Quality Inspection features may include but are not limited to defects such as tears, bubbles and contamination, dimensional measurements such as diameter, lens thickness and refractive power detection. The rubber pads at the tips of the finger units **41, 46, 47, 48 & 49** may include Hall effect sensors, Biometric sensors and other optional sensors as required by a specific process. The Robotic Right hand, the Robotic left hand working in close coordination with each

other's capabilities, adds a very important capability in automating different processes, not realizable in related art.

In a fourth embodiment of the present invention a configuration that is capable of being
5 implemented in the glass inspection industry is described. The Robotic left hand camera
43 in Fig 11 in coordination with the imaging system unit **18 in Fig 1** of the Robotic
Right hand, may be utilised to inspect a glass object (for example: a mobile phone screen
or bezel glass) for defects and dimensions to determine if the glass is defective.

10 In a fifth embodiment of the present invention a configuration may be implemented in the
Surgical accessories manufacturing industry wherein accuracy and hygiene is particularly
important and mandatory. Accessories may include but not limited to Cardiothoracic
instruments, delicate microsurgical heart valves...etc. Post manufacturing the same set of
Robots may be used to implement the quality assurance processes to inspect the
15 manufactured products, before dispatch to customers.

In a sixth embodiment of the present invention a configuration may be implemented
wherein the Robotic hands are adapted to read and interpret printed information on
packages such as envelopes, boxes and containers for the purpose of sorting and binning
20 them according to a predetermined set of rules. For eg. The Multifunction Robotic hands
may be adaptable in the postal department and warehousing industry to sort and bin the
packages according to their ZIP codes.

The Multifunction Robotic hands with built-in artificial intelligence, are capable of reconfiguring themselves by replacing an entire Robotic hand with a differently configured Robotic hand or to replace a specific set of Robotic finger units, without any human intervention. This feature enables the Robotic hands to scale and adapt themselves,
 5 whenever they are required to operate for a new application or if a modified process is required to be implemented in the same application. The interchangeability and interoperable functions that is achieved through standardised interface (**22 in Fig 5 and Fig 5a and 42 in Fig 11**) makes the Robotic hands reconfigurability simple, enabling quick and easy deployment in new processes under the same or different operating
 10 conditions, not possible in prior arts.

Referring to **Fig 12**, the flow of the process starts at **100** wherein a contact lens within a blister pack is to be removed and inspected. In Step **102**, the blister pack **45 in Fig 1** is presented under the imaging system **18 in Fig 1**, to identify the package outline and locate
 15 the edge of the blister foil **65 in Fig 1**. The positional information determined in Step **104** of **Fig 12** is communicated to the computer system (not shown) in **Step 106** which instructs the Robotic Right hand **20 in Fig 1** to engage the motor shaft **30 in Fig 1** with the blister foil **65 in Fig 1**. At **step 108** the foil engagement is complete. If not complete the process restarts at **step 106** to retry the foil engagement process. In **step 110** the motor
 20 **30 in Fig 1** begins to rotate in the clockwise direction while simultaneously moving the motor assembly towards the backend of the blister, and in the process peeling the blister foil **65 in Fig 1** until it is fully detached from the top side of the blister pack **50 in Fig 1**. In the next **step 112** of the Robotic right hand, the blister foil is discarded and the Robotic Right hand moves to the next **step 114**. In step **114**, the imaging system commands the

Robotic Right hand to pick up the contact lens from the blister pack **50 in Fig 1** and place it on a pedestal **44 in Fig 11** for the imaging system **18 in Fig 1** to inspect the lens. The imaging system characterises the contact lens based on a set of rules and communicates the results in **step 115** to the Robotic Right hand which will then pick up the contact lens
5 from the pedestal. The results are consolidated in **step 115** and communicated at **116** after which sorting takes place in **step 117**. The contact lens is picked up from pedestal **44 in Fig 11** and placed into different containers based on the decision in **step 118** into containers **120-124**. It is important to note that the number of categories of containers can vary based on the configuration of the Quality assurance system. The process ends at step
10 **126** after discarding the empty blister in the Robotic left hand in **step 119**.

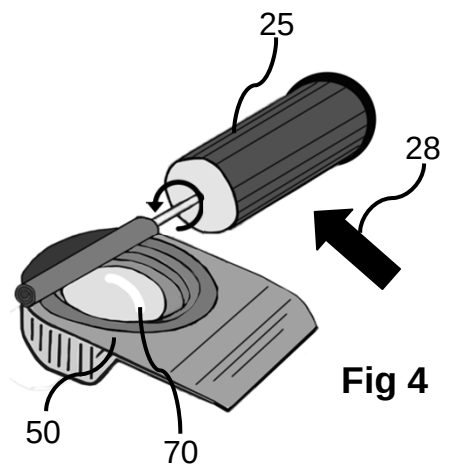
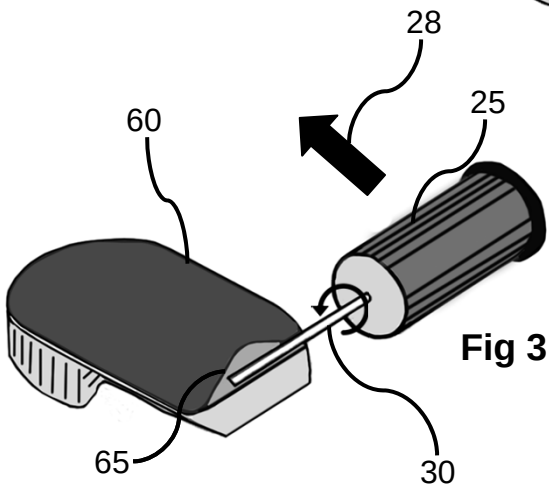
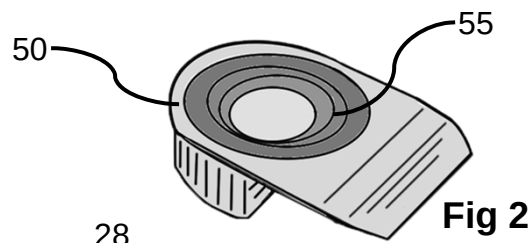
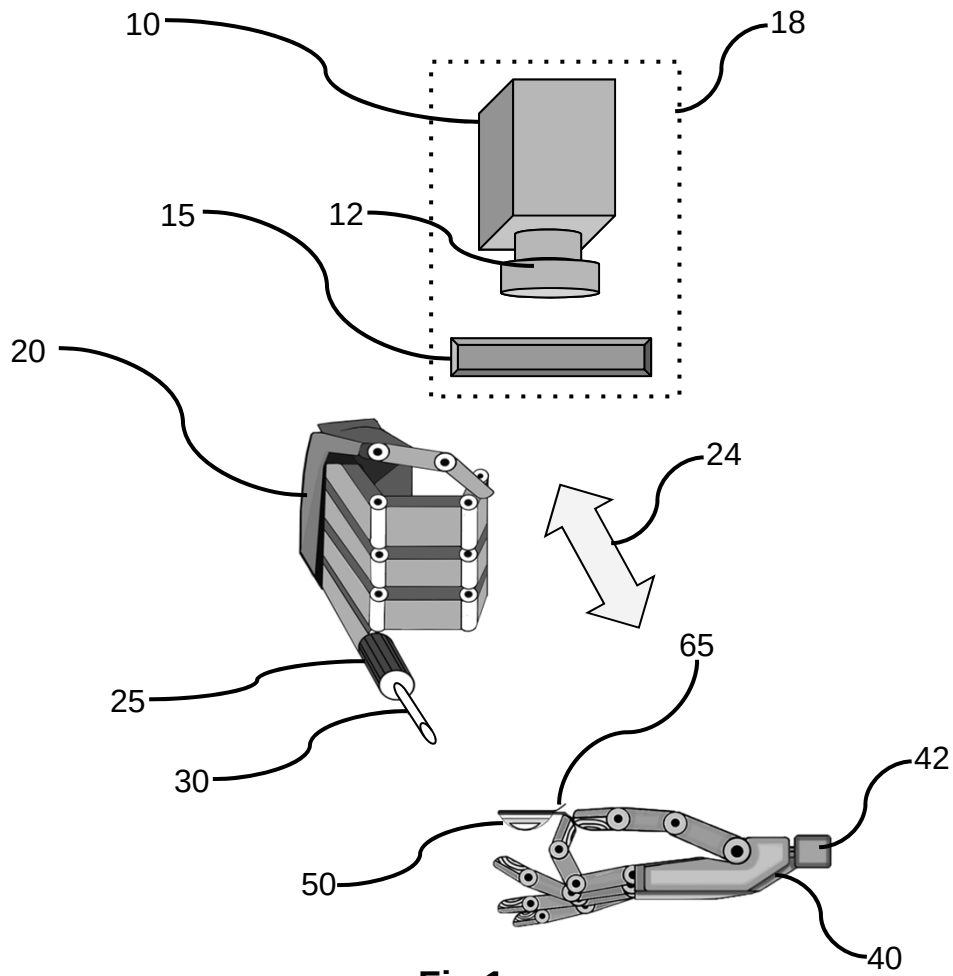
The unique design of the Multifunction Robotic hands and its associated finger units makes it possible to realize all possible actions and movements that include gripping, holding, cleaning, brushing, dosing, pickup and placement of an object, opening and
15 closing a cap of multiple variety of containers, enable them for deployment not only in the quality inspection processes but also in manufacturing processes where accuracy, reliability, consistency and hygiene are of great importance.

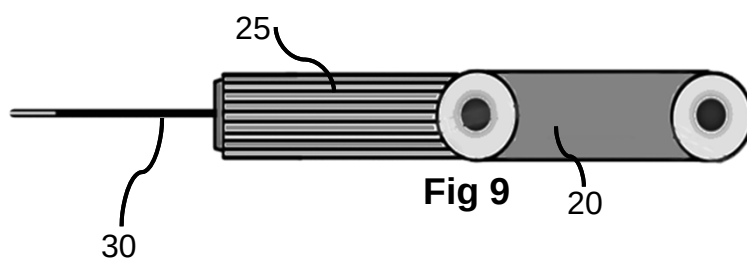
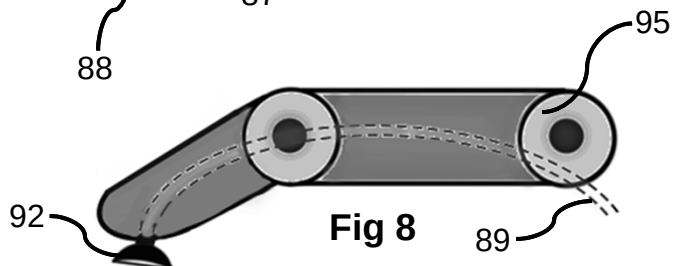
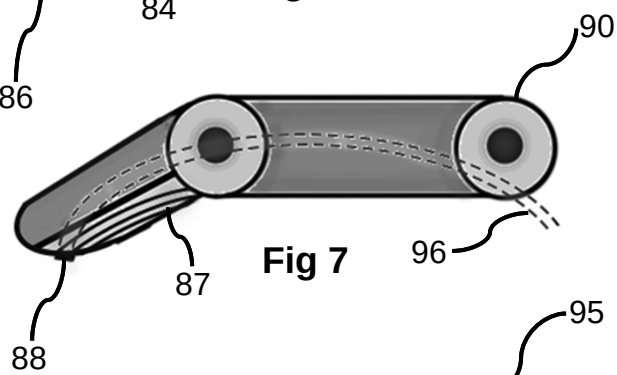
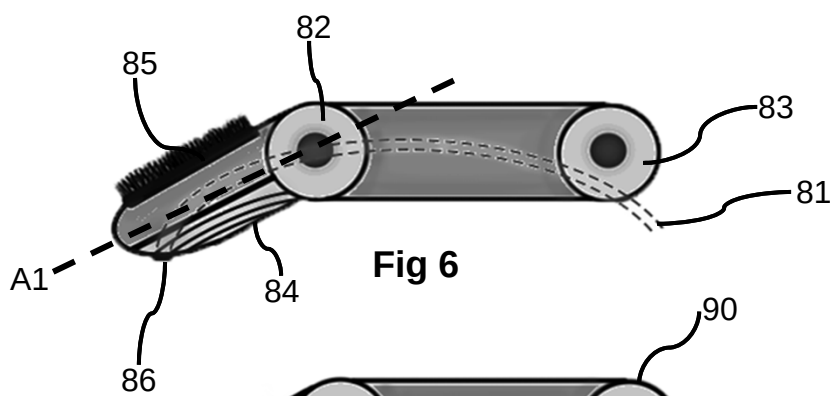
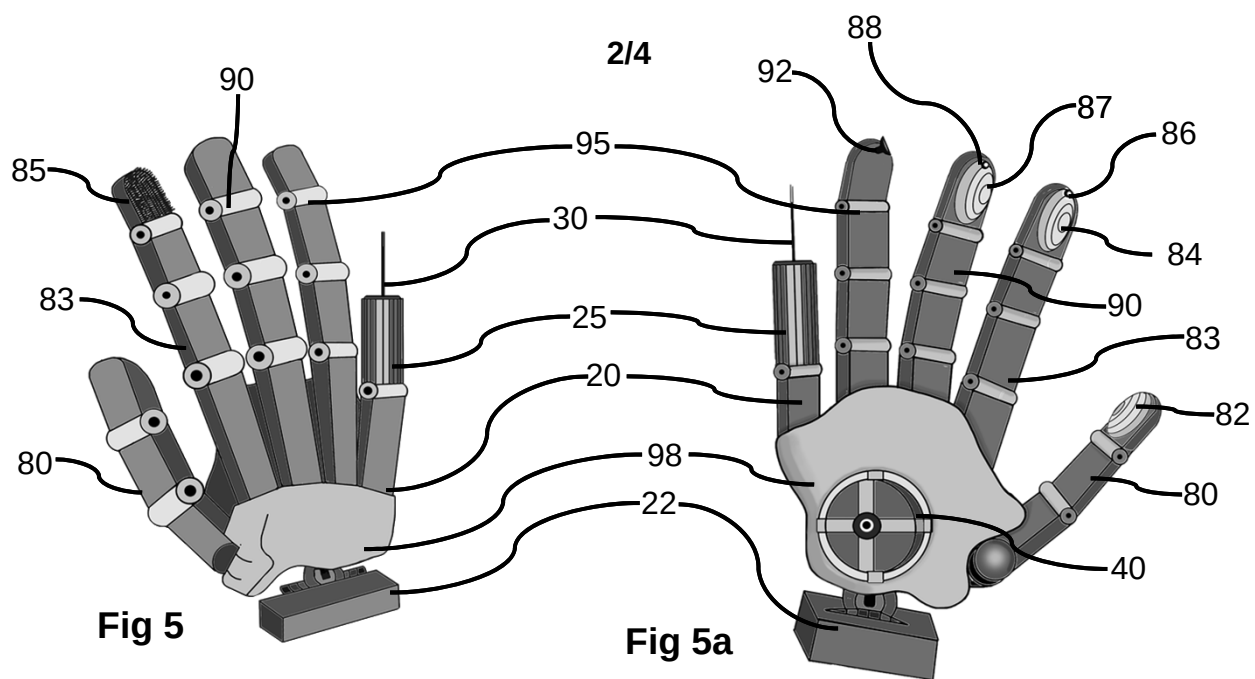
Hereinbefore, the Multifunction Robotic hands according to the embodiments of the
20 invention are described, but the invention is not limited to the above embodiments, and may include various modifications appropriately made in a range without departing from the spirit thereof.

ABSTRACT**ADAPTABLE MULTIFUNCTION ROBOTIC HANDS**

Toolable modules, each having a set of functions and capabilities which are configurable
5 to function cooperatively, to create a set of Robotic arms. Each finger of the module
enables a specific task to be accomplished, providing multiple degrees of movements,
enabling the Robotic arms to be deployed in highly precise applications and capable of
responding to complex tasks. In coordination with an imaging system and a control
system the functionality of the Robotic arms are programmable, scalable and configurable
10 in addition to being able to communicate with the external interfaces in a predetermined
protocol, thereby providing “Plug and Play” functionality.

Figure 1





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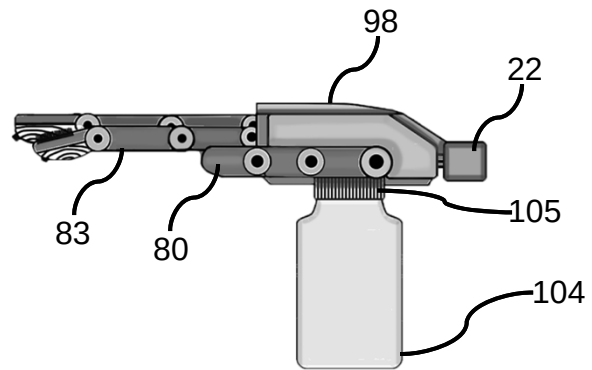


Fig 10

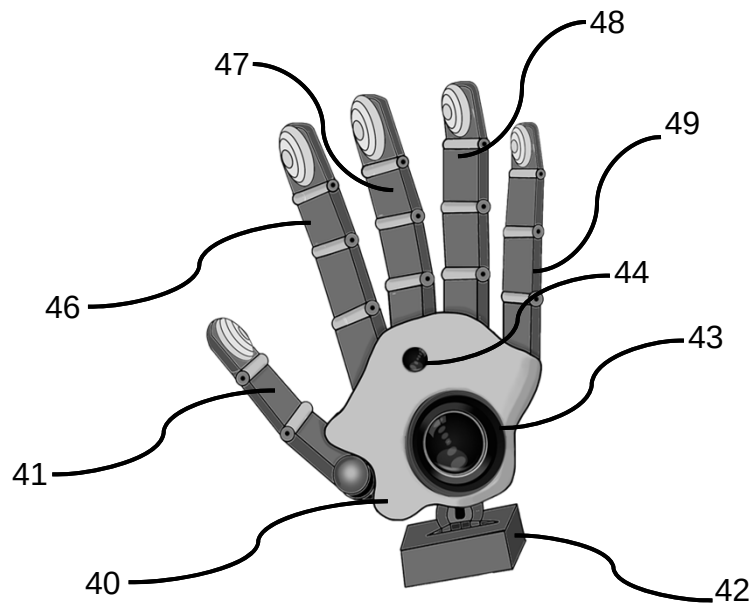


Fig 11

Process Flow chart for Contact lens Quality Inspection

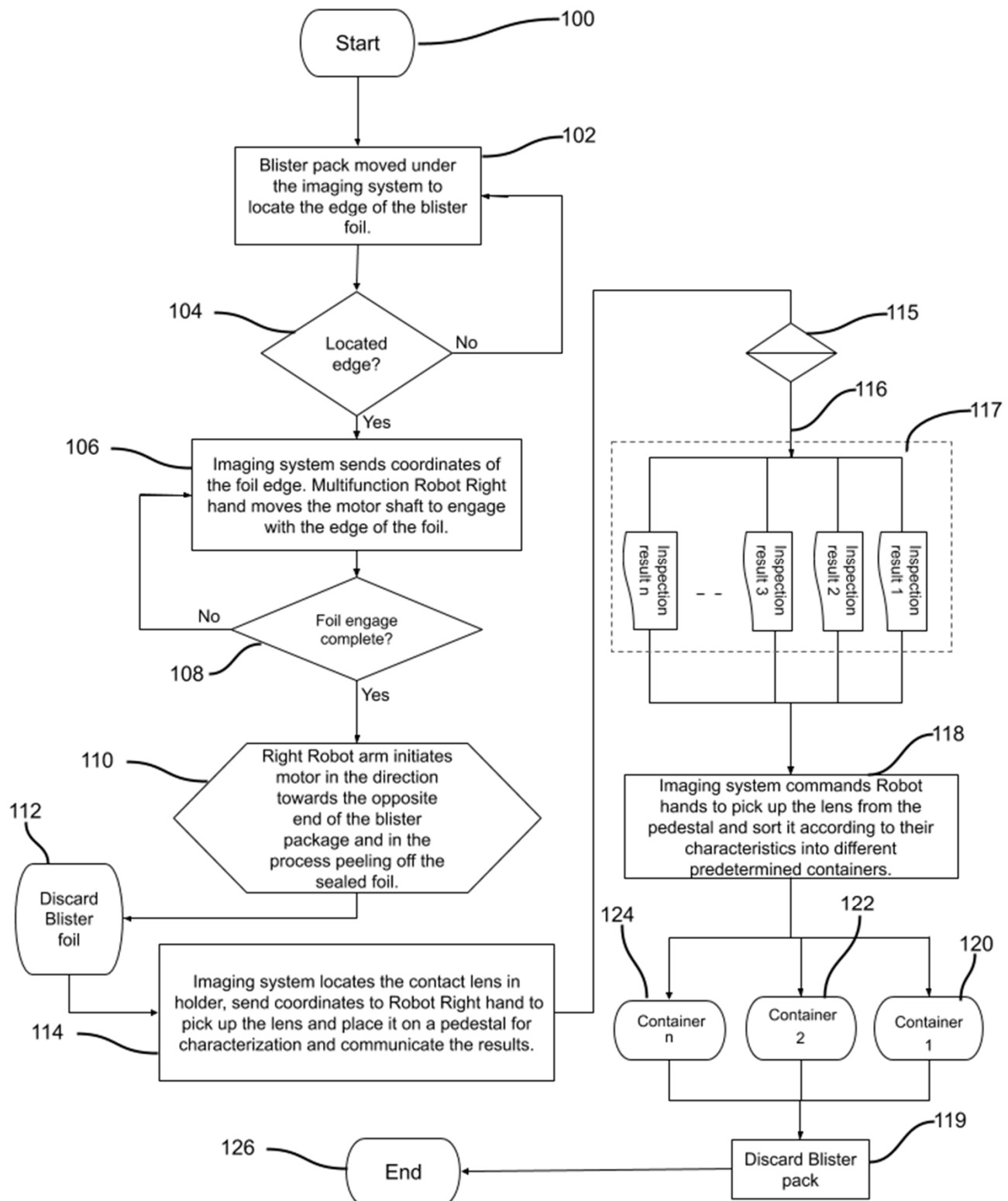


Fig 12