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Small Objects Manipulation

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1. Introduction

The bulk of the contemporary requirements for grippers used in robotics, microrobotics and environment exploration, as well as industrial automation tasks are usually incompatible and it is very hard to find a optimal technical solution that would satisfy the requirements of each specific field of implementation. There is a recent trend for even higher and stricter requirements for the capability of dosing of the applied force during gripper object manipulation of soft (surgery) or miniature objects (using electron microscopes), remote robot teleoperation (environment exploration and sample extraction) and others. One of the possible alternatives of a device suitable for the increasingly demanding and diversified fields of application, as well as practical implementation of the functions required is the use of a new type of linear actuator [4] with force, position and visual feedback [5].

2. Design and principle of operation

Fig. 1 shows the assembly drawing of the developed gripper.

Fig. 2 shows the construction of the developed gripper, where:

1, 2 – ferromagnetic cores; 3, 4 – windings; 5 – chassis; 6 – permanent magnet; 7 – shaft; 8 – rack; 9, 10 –gears; 11, 12 – fingers; 13, 14 – gripper jaws, 15 – digital encoder; 16 – sensor FSS

The linear actuators with a movable permanent magnet possess one important advantage, namely the simple design which makes them especially suitable in cases where the overall size has to be kept to a minimum.

On the two ferromagnetic cores 1 and 2 are wound the windings 3 and 4, which are powered in opposite directions. The permanent magnet 6 is situated in the air gap between both cores and has the possibility to move longitudinally parallel to the cores together with the permanently fixed to it shaft 7 and gear rack 8. The permanent magnet is magnetized in the direction shown and is made out of material NdFeB 40 MGOe. Both ferromagnetic cores are made of ARMCO.

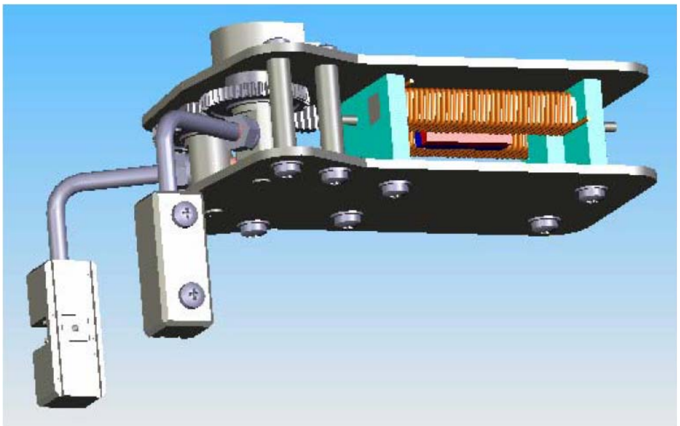

Fig. 1. Assembly drawing of a gripper with linear actuation

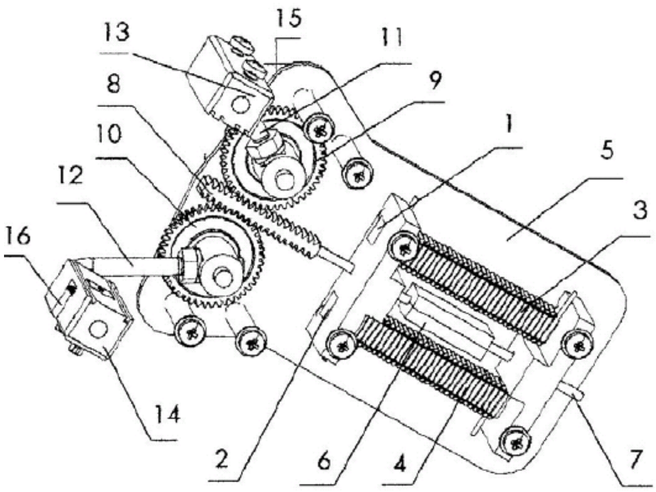

Fig. 2. The construction of a gripper with linear actuation

3. Principle of operation of the device

During its longitudinal displacement along the axis of shaft 7 under the influence of force **F** the magnet 6 brings to motion the rack 8 and in turn rotates the gears 9 and 10 coupled to it. Depending on the direction of movement the rack 8 rotates in either way, but in opposite directions the gears 9 and 10 with the attached to them fingers 11 and 12 and respectively the jaws 13 and 14. Attached to jaw 14 is a FSS Low Profile Force Sensor (shown as element 16 on Fig. 2) produced by Honeywell [9] with dimensions of just 4×4×10 mm.

The jaws of the gripper can be exchanged in a timely fashion depending on the concrete requirements of application at hand and the type of the manipulated objects. The FSS sensor can measure accurately the force applied during gripping in the effective range of 0 to 1500 g and due to its linear characteristic, its output can be easily transformed into DC voltage. Another function of this sensor is to detect the moment of contact between the jaws and the surface of the manipulated object, respectively the moment of its release.

A disadvantage of the implemented linear electromagnetic actuator is that it can be used only in combination with a device providing positional feedback. In this case this disadvantage is avoided by the implementation of the encoder 15 shown on Fig. 2, which is coupled to the shaft of the gear 9, again shown on Fig. 2. The finger 11 is fixed to the gear 9 and to the finger itself is coupled the exchangeable jaw 13. As a result of the high measuring resolution of the encoder 15 the proper accuracy of positioning the gripper jaws is ensured [8].

The functioning of the device in different modes of operation is realized by controlling the value of the DC voltage supplied to the coils of the electromagnetic actuator and monitoring the output value of the encoder and the FSS sensor. Changing the polarity of the supplied voltage will correspondingly either open or close the gripper jaws. The speed with which this will happen is proportional to the value of the voltage supplied. When contact between the gripper jaws and the object to be manipulated is established (an indication of which is received by the FSS sensor output) the force thus applied upon the object is proportional to the supplied voltage as well. When working with automatically oriented symmetrical objects in the moment of contact the corresponding output value of the encoder gives accurate information for the dimension of the object between the points of contact with the gripper jaws. When used in closed-loop mode this information could be used for measuring the object dimension deviation from the desired target value. By rotating the gripper (around the *Z* axis) and thus taking several measurements of the object dimensions (by establishing contact with the gripper jaws each time) reading the encoder output the shape of the object could be identified or dimension deviation measurements along several planes could be performed.

After establishing contact with the manipulated object and subsequent increase of the force the gripper jaws exert on it (via increase of the DC voltage supplied to the actuator windings) the change of encoder reading (i.e. object deformation) could allow for determination of the hardness of the object, as well as the optimal gripping force which would allow for the proper execution of all desired manipulations of the object (i.e. enough friction force so there is no slipping for example).

4. Implementation of the gripper as a haptic interface

Robotic teleoperation in combination with visual feedback, especially when it comes to manipulation of small objects, is finding an increasingly wider integration into practice. The practical realization of this process, as well as ensuring the safe and non-destructive handling of objects when handling them with grippers is not possible without the use of force feedback during their manipulation, which can be done by an operator only via a haptic interface. The main requirements for a haptic interface is for it to provide means for easy and intuitive teleoperation of the robots by providing in the same time a wide enough dynamic range of gripping forces it can represent as well as fast enough response to force feedback signals [7].

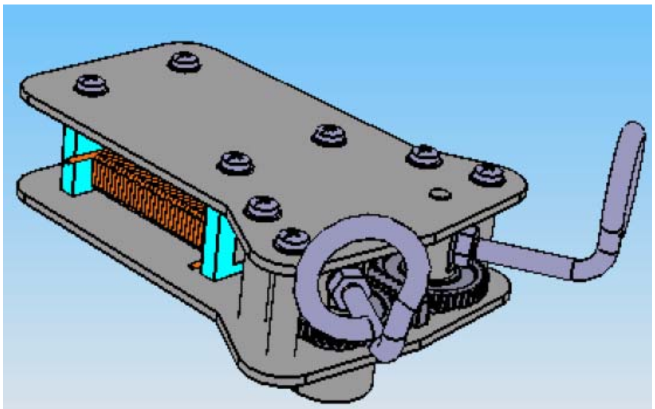

Fig. 3. Haptic interface

Fig. 3 depicts the fast and easy transformation of the developed gripper into a haptic interface. For this purpose instead of the gripper fingers and jaws two ring handles are mounted in their place.

With such means the operator is able to control the gripper while received information about the exerted gripping force via the force feedback exerted on this fingers by the handles actuated in turn by the windings of the now haptic interface. The inherent capability to scale the force feedback allows the operator to control various grippers while using the same device irrespectively of whether the application is in the macro, micro or the nano-sphere or whether an optical camera or an electronic microscope is used as means of video feedback. The degree to which the handles of the haptic are manually opened or closed determines accurately, by monitoring and feeding to the control system the reading of the encoder, the degree of opening of the controlled gripper. The information of how much force is exerted by the controlled gripper upon the manipulated object is translated back to the operator by means of adequate in value voltage on the windings of the linear actuator. The thus actuated in a corresponding direction (opposite to the one generated by the manual operator input realized by manipulating the handles) linear actuator [6] will produce a resisting force in the haptic device and thus provide the means for tactile feedback regarding the manipulated object (naturally in the applied scale).

5. Conclusion

The presented specialized robot gripper with adjustable gripping force and limited capability for object identification is an attempt to offer a solution that satisfies the complex requirements towards grippers designed for teleoperation and manipulation of small objects of various hardness. The developed device is aimed for use in the following application areas: remotely operated groups of mobile agents (microrobots); measurements of object parameters and probe retrieval from the environment; manipulation tasks in microbiology as well as microassembly operations; operations involving small and non-adhesive objects; and others. Experiments aimed to evaluate the design applicability and suitability for industry as well as research purposes are planned for the immediate future.

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Манипуляции с маленькими объектами

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(Р е з ю м е)

В статье разсматриваются захватывающие устройства с линейными двигателями для работы с маленькими объектами. Представлены конструкция и принципы оперирования устройства. Описывается работа как испольнителного механизма, также и задающего устройства в руках оператора. После оснащения с позиционными и с силовыми сензорами можно пользовать эти устройства в микромедицине, микроробoтике и др.