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Innovative Design of Robot Hands for Space Activities

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Extended abstract

In the last decade a number of devices for robotic manipulation in the space environment has been proposed and even tested in space [1]-[3]. Nevertheless, these devices were equipped with simple (1-3 dof) grippers while the goal, currently pursued, is to completely substitute astronauts in the execution of hazardous or time consuming tasks. Therefore, more dexterous end-effectors have been proposed and anthropomorphic robot hands are currently under development, which closely mimic, as far as structure and functional capabilities are concerned, the human hand (e.g. the Robonaut Hand [4] and the DLR Hand II [5]). Nevertheless, the way towards a device with the same capability of the human hand and, at the same time, those characteristics of reliability and safety required by space missions, is still long. Anthropomorphic robot hands are in general characterized by a very complex structure, because the large amount of degrees of freedom, actuators, sensors and, more generally, because the very large number of different parts and components.

Fig. 1 UB Hand III: the last prototype and the CAD model of the next version.

Aim of this work is the development of an articulated robot hand resulting from an optimal trade-off between dexterity and complexity. The key point of the overall project (called UB Hand III – University of Bologna hand, third version) is an innovative mechanical design based on compliant mechanisms [6]. Each finger is made of rigid elements (the phalanges) connected through elastic hinges, obtained from steel spiral coils that are used also as sheath for tendon routing, that allow relative motion due to self bending. Their structure presents four joints: the proximal allows adduction-abduction (yaw) motion, while the intermediate and the distal ones permit finger bending. Each joint is actuated by forces exerted on the phalanges by remotely actuated tendons, that slide inside routing paths along the finger structure and pass through the hinges along their bending axis. After early attempts [6], [7] to develop "monolithic" fingers with
hinges and tendons integrated in a single item, the current version adopts different materials for the hinges, the phalanges structure, and the tendons, [8].

By exploiting the finger structure the sensory apparatus (including position and force sensors) has been integrated in the hand, [8]. In particular, the forces exchanged with the environment are measured by monitoring (by means of strain gauges) the deformation imposed by the tendons on the purposely shape connector, which link the tendon with the actuated phalange. The same principle (the measure of a deformation) is used to know the configuration of the fingers. By measuring the momentum imposed by a bended coil, which behaves like a spring, on a sensorized element it is possible to know the bending angle and, therefore, the relative positions between the phalanges.

Furthermore, this skeletal structure is particularly suitable to be covered with thick layer of material which can have a twofold function:

- Thermal and mechanical insulation during extra-vehicular activities;
- Soft interface for fine manipulation tasks (e.g. manipulation of biological samples and scientific tools).

The proposed design produces a noticeable simplification of the hand structure (with positive consequences on its reliability) and shows great versatility, allowing the development of many alternative hand configurations thanks to the following important features:

- **Modularity.** The hand is obtained repeating a modular finger built by low cost moulding process. The complexity of the system can be customized according to the needs of the application. For example, a three fingered device could be enough for easy grasping tasks, while in tele-operated space applications the use of five fingers could allow a good reproduction of the human hand dexterity.

- **Possibility to change the actual number of d.o.f without changing the finger structure.** The adopted kinematical configuration is suitable for a reduction of the number of d.o.f. by coupling some of the joints.

- **Compatibility with any kind of linear actuation.** The adopted finger design is not dependent of a particular kind of actuation and is compatible with future availability of new actuators, e.g. artificial muscles.

The final version of this paper will present in detail the above points, and preliminary experimental results obtained on the first prototypes of the hand will be reported and discussed.

**References**


