Definition of actuation and kinematics capabilities of robotic hands for grasping and manipulation of common objects.

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The design and realization of multifingered hands is an important research topic in the robotic community and it has been widely studied since the mid 80s. Despite the initial purpose in developing such devices was to overcome the lack of flexibility of traditional end-effectors, nowadays one of the driving issues is to mimic the humans hand capabilities and, more in general, to improve their level of anthropomorphism. Anthropomorphism is sought for a number of reason and at various levels: from the possibility of imitating the way humans approach fine manipulation problems (where dexterity is necessary), to the employment as prosthetic devices (where aesthetics is an important issue).

In order to achieve an high level of anthropomorphism in robotic hands, the first issue is the definition of a kinematic structure able to reproduce the natural movements of the human hand. Moreover, due to the high mobility required to emulate the human capabilities, the robotic hand must be activated by a large number of actuators, so augmenting the design complexity, the miniaturization issues, the cost, and the weight of the device.

On the other hand, focusing on the tasks that the hand has to perform, designers tried to identify the better trade off between hand complexity and capabilities. Robotic grippers and underactuated hands are remarkable examples of simplifications in both the hand kinematics and actuation. With reference to task complexity, grasp tasks can be accomplished with very simple end-effectors, whereas manipulation tasks need several actuated degrees of freedom in the robotic hand.

In the proposed analysis, the robotic hand kinematics and the actuated degrees of freedom (the number of movements that can be accomplished, that is strictly related to the number of motors that drive the hand) are considered with respect to a set of tasks performed on common (for humans) objects.

Three classes of maneuvers are considered: 1) grasping; 2) dexterous maneuvering; 3) re-grasping. A suitable instance of these maneuvers have been defined within a domestic environment by means of a set of tasks. Some of the proposed tasks, such as the handling of a pencil, the rotation of an heavy object, and grasping of a paper holder, are schematized by a set of pictures reported in Fig. 1. In these tasks, the three classes of maneuvers are presented sequentially. The first common step is the grasp of the object. Hence, the object is manipulated and the capability of moving the object by means of the sole finger movements is considered (the hand blocked in a fixed position). Due to the limited finger workspace, the needs for re-grasping maneuvers is considered in order to perform large object displacements. Re-grasping is necessary each time one performs a manipulation, and a finger arrives at the limit of its workspace in between. In all the proposed tasks and, more generally, in the majority of manipulation tasks performed by humans, the object is moved with one degree of freedom at a time. Nevertheless, considering the whole set of tasks, several degrees of freedom must be provided to the object.

Based on these considerations, the discussion will be expanded to more general cases, trying to individuate the minimum requirements and the fundamental features in terms of kinematics and actuation for an anthropomorphic robotic hand conceived for applications in an unstructured human-like environment.

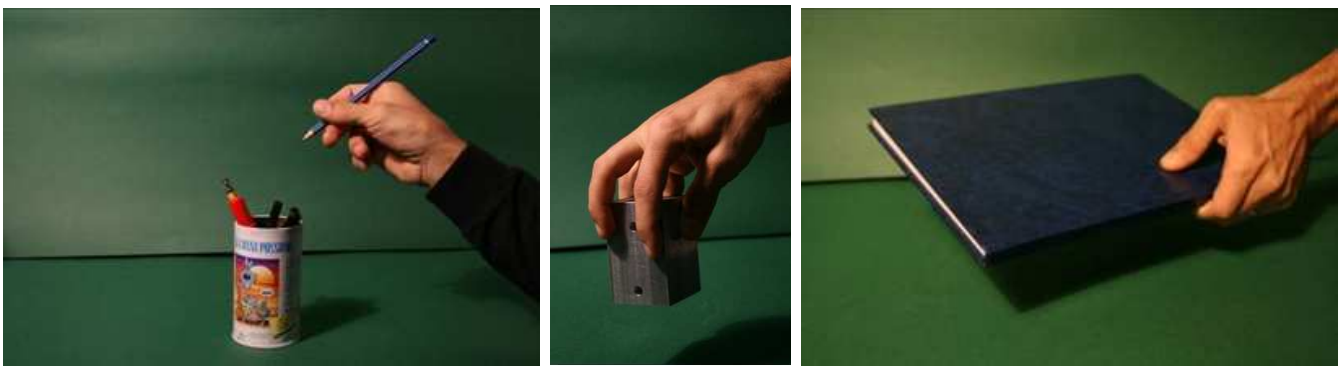

Fig. 1. Representation of tasks. Grasping (a), dexterous maneuver (b), re-graping (c).

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