Analysis of Human Grasping Using Self-Organizing Map

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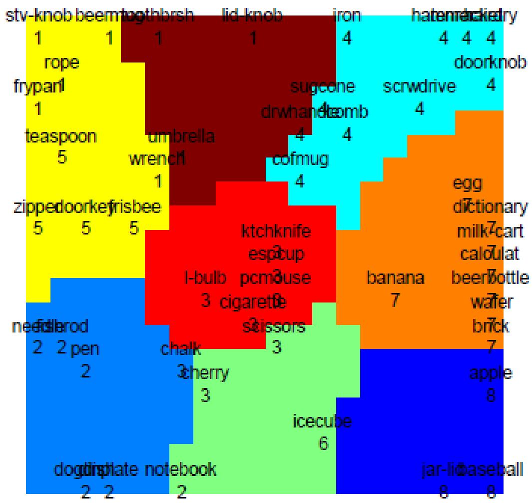
The human hand has a very complex structure with many degrees of freedom (dof). However, previous studies have shown a high degree of correlation in finger joint angles when grasping objects across a wide range of shapes and sizes. It was proposed that hand postures used for grasping and exploratory procedures lie in a low dimensional space. It has been proposed that this synergic dimensionality reduction might be a way in which the Central Neural System controls the highly redundant musculoskeletal system of hand [1], a concept that has been exploited for real time planning algorithm for robotic hand [2]. However, full implementation of these algorithms would benefit from a better understanding of how human grasp postures relate to the shape of the objects or to the task. Although grasp taxonomies have been proposed [3], these taxonomies are based on qualitative rather than quantitative observations.

In the present work we trained a 20×20 Self-Organizing Map (SOM) to analyze and visualize the dimensionality reduction and classification of the hand postures captured on one subject during imagined grasping of 57 common objects [1]. Using U-Matrix as an output of the SOM, our results showed clear boundaries between groups of grasp postures. Furthermore, we used hierarchical clustering on the trained SOM (400 units, 15 dimensions each) to quantify the categorization of the grasp postures, as well as to group the joints that have high covariation. Interestingly, the clustering dendrogram of grasp postures in joint space showed similar structure as those from a well-known grasp taxonomy [3]. They can be first divided into power and precision grasps and then further subdivided according to the object shape and size. We also showed that the boundaries between clusters were functionally related to joint groups. For instance, power grasps of spherical and block shaped objects were distinguished by the magnitude of abductions of the four fingers, which suggests that subject tended to distribute the digits more evenly for spherical objects than for block/cylindrical objects.



Our results revealed the relation between the human grasp postures and the shape or function of the target objects. The SOM approach was shown to be potentially useful for designing adaptive grasp planning algorithm based on visual perception of the objects.

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