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# Quantitative hierarchical representation and comparison of hand grasps from electromyography and kinematic data

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**Abstract. Motivation:** Modeling human grasping and hand movements is important for robotics, prosthetics and rehabilitation. Several qualitative taxonomies of hand grasps have been proposed in scientific literature. However it is not clear how well they correspond to subjects movements.

**Objective:** In this work we quantitatively analyze the similarity between hand movements in 40 subjects using different features.

**Methods:** Publicly available data from 40 healthy subjects were used for this study. The data include electromyography and kinematic data recorded while the subjects perform 20 hand grasps.

The kinematic and myoelectric signal was windowed and several signal features were extracted. Then, for each subject, a set of hierarchical trees was computed for the hand grasps. The obtained results were compared in order to evaluate differences between features and different subjects.

**Results:** The comparison of the signal feature taxonomies revealed a relation among the same subject. The comparison of the subject taxonomies highlighted also a similarity shared between subjects except for rare cases.

**Conclusions:** The results suggest that quantitative hierarchical representations of hand movements can be performed with the proposed approach and the results from different subjects and features can be compared. The presented approach suggests a way to perform a systematic analysis of hand movements and to create a quantitative taxonomy of hand movements.

**Keywords:** Hierarchical Trees, Electromyography, Kinematics, Hand Movements, Robotics

## 1 Introduction

The most advanced robots are still inefficient and lack adaptability in comparison with animals, in particular for tasks characterized by high variability, such as grasps and object manipulation. The human hand can perform a wide number of different movements, that allow it to easily grasp very different objects. Instead, robotic manipulators have not reached a similar level of dexterity in the interaction with the environment. Several qualitative taxonomies of hand grasps have been proposed in scientific literature in order to model the interaction of the human hand with objects. However they have not been quantitatively evaluated. Properly modeling human hand grasps and movements can allow to improve robotic hands by making them more similar to the human hand. Thus, quantitative studies that analyze, model and compare human hand movements can improve robotics (as well as, obviously, other fields).

Robots that aim at grasping and manipulating objects, such as industrial robotic hands and prostheses, all lack reliability and robustness in real life settings. In industry, automated warehouses are successful at removing processes such as walking and searching for items. However, automated handling of goods in unstructured environments still remains a difficult challenge.

The human hand is highly dexterous and can be used for many diverse tasks. It includes 15 joints (not including carpus and metacarpus), leading to more than 20 degrees of freedom. During the last 30 years, scientific researchers developed several categorizations of hand grasps. Most of the them include a division between power and precision tasks, an idea originally proposed by Napier et al. in 1956 [1] and that influenced literature afterwards (e.g. [2]). However, all of the presented works were based on qualitative approaches, thus they are prone to researchers' view and a quantitative description of how the human hand interact with different objects is still missing.

Quantitatively modeling human hand can be important for several scientific fields. In robotics, it enables the comparison between real human hands, industrial manipulators, dexterous robotic hands and prostheses, allowing to better define their requirements and to foster the development of devices that are more capable to interact with an environment characterized by high variability (increasing also the diffusion of dexterous robotic hand prostheses, which is currently low [3]).

The development and evaluation of quantitative representations of hand movements requires the measurement of specific biomedical data. Kinematic and muscular data can provide a complete view of hand functions and they have been widely studied for rehabilitative robotic applications.

In this work, we quantitatively analyze the similarity between hand movements in 40 subjects. Surface electromyography (sEMG) and the relative variations between joint bending angles of a data glove allow a hierarchical quantitative characterization of the hand movement dynamics and kinematics for each subject, in order to identify functional similarities and variability. The proposed approach suggests a way to perform a systematic, quantitative analysis of hand movements in order to develop a quantitative taxonomy.

## 2 Methods

The data are from Ninapro[4], a publicly available database that aims at improving the control of robotic hand prostheses. We used only a part of the entire dataset (the 2nd), which includes sEMG and cyberglove data of 40 subjects while repeating 20 hand grasps, as described in detail in the reference papers [4]. Hand kinematics were recorded using a 22-sensor CyberGlove II (CyberGlove Systems LLC [5]). Electromyography data were recorded with a Delsys Trigno wireless system at 2 kHz [4].

The analysis of sEMG and kinematic data includes pre-processing (i.e. filtering, synchronization and relabeling), windowing (window length: 200 ms; overlap: 100 ms), signal feature extraction [4, 5] and the computation of the hierarchical trees. We tested the following signal features: Root Mean Square (RMS), Mean Absolute Value (MAV), Integrated Absolute Value (IAV), Waveform Length (WL) and Time Domain Statistics (TD) [6].

One hierarchical tree was computed for each subject, for each modality-feature combination. For each feature, the means of the signal features obtained for each movement were compared with the Mahalanobis distance and used to create dendrograms first and afterwards phylogenetic trees.

Measuring the similarity between hierarchical trees allows to compare them and to evaluate their variability. The comparison of hierarchical trees is often performed using the tree edit distance [7,8], which is computed as the minimal-cost sequence of node edit operations required to obtain one tree from another [7,8]. The possible operations include: deleting a node, inserting a node and renaming the label of a node.

## 3 Results

The obtained taxonomies have been compared both among subjects and among features. The comparison of the signal feature taxonomies show that IAV and MAV features produced the same tree for almost all the considered subjects for both EMG and glove signals. Anyway, the trees related to the other features have some common characteristics: for example *Extension Grasp* and *Power Disk* are closely related for Subject 2 (Fig. 1a and Fig. 1b). Furthermore, IAV and MAV are very similar to RMS results, while TD tree is the most different from the others (Fig. 1c). The previous assertion is valid for both EMG and GLOVE signals, confirming that the represented information is coherent among the two kind of signals. The comparison of the subject taxonomies shows that a common behaviour could be highlighted among the different individuals. Some

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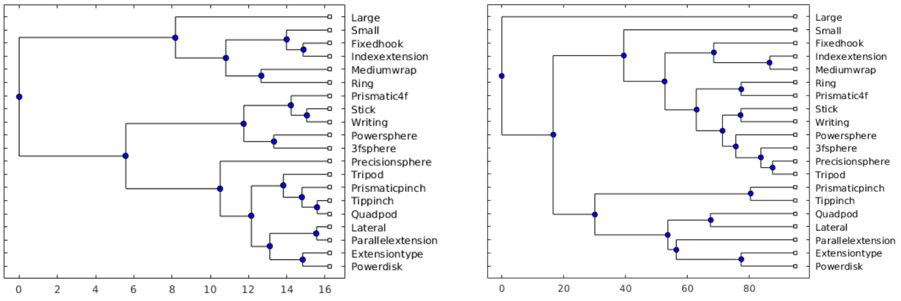
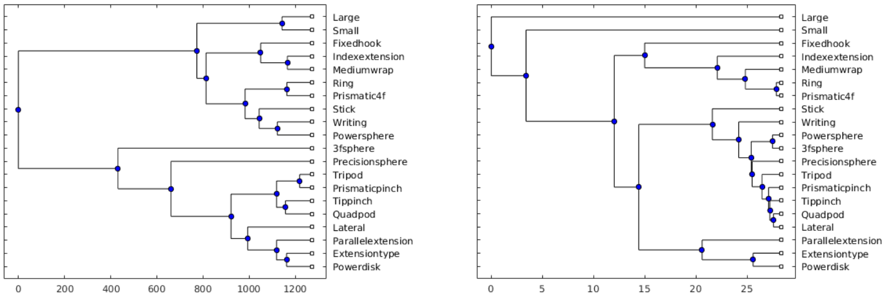
[4] http://ninapro.hevs.ch/

[5] url: http://www.cyberglovesystems.com/

movements are strictly related among almost every subject, this is the case of *Extension Grasp* and *Power Disk Grasp*. While the majority of subjects have a similar behaviour, some of them vary from the average, as it happens for Subject 9 (Fig. 1d). In particular, this subject's subtree is populated by a wide set of movements for both IAV and MAV features for EMG signals In fact, in this case movements like *Stick Grasp*, *Writing Grasp*, *Power Sphere Grasp* are in the same subtree, while trey are usually separated in different branches.



(a) Subj:2, Feat:MAV, Data:EMG (b) Subj:2, Feat:MAV, Data:GLOVE



(c) Subj:2, Feat:TD, Data:EMG (d) Subj:9, Feat:MAV, Data:EMG

Fig. 1: Hierarchical trees created by using (a) MAV features on EMG data from Subject 2, (b) MAV features on Glove data from Subject 2, (c) TD features on EMG data from Subject 2, (d) MAV features on EMG data from Subject 9

## 4 Conclusions

The results suggest that quantitative hierarchical representations of hand movements can be performed with the proposed approach and the results from different subjects and features can be compared. The presented approach suggests a way to perform a systematic analysis of hand movements and in the near future we plan to create to quantitative taxonomy of hand movements. This would be the first attempt since usually taxonomies are based on a qualitative approach.

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