KINEMATIC SYNERGIES OF HAND GRASPS

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Introduction

The use of the hand involves the coordination of multiple degrees of freedom (DoF) and the exploitation of kinematic redundancy. Hand kinematic reduction (synergies) has been applied widely to study grasping postures [1] and allows for defining useful metrics for motor assessment and rehabilitation or improving prostheses control. The aim of this study is to extract representative hand kinematic synergies from grasps, considering their frequency in activities of daily living (ADL) and their relevance for personal autonomy [2].

Methods

We have used data from two previous studies: filtered kinematic data of different types of grasps from a public database (Ninapro) [3], and the grasp frequency and relevance for personal autonomy [2]. In the first study, 77 subjects performed 20 grasps (reaching, grasp and immediately release), extracted from the ADL literature [4]. Each subject repeated each grasp 6 times. Fifteen hand joint angles were measured at 25 Hz with an instrumented glove: metacarpophalangeal (MCP1 to MCP5, 1 to 5 meaning thumb to little digits) flexion, thumb interphalangeal (IP1) flexion, fingers proximal interphalangeal (PIP2 to PIP5) flexion, flexion and abduction of the thumb carpometacarpal (CMC1) joint, relative abduction between fingers (middle-ring; MCP3-4_A, and ring-little; MCP4-5_A), and palmar arching (PArch). Relative abduction between index and middle finger was not included due to noise problems. In the second study, the relevance (in percentage) for personal autonomy of a 9-type grasp classification was obtained [2] during the performance of 2300 grasp actions in ADL representative of the ICF.

In this work, each grasp repetition was rescaled to 1000 frames and the data of all repetitions for each grasp of each subject were averaged. Then, both grasp taxonomies were matched, so that the 20 grasps were collapsed to 7 grasps (non-prehensile and hook grasps discarded, since they were not measured) and the number of frames was rescaled again to be proportional to the relevance for autonomy, according to Table 1 [2].

Cyl	PpPinch	Lum	LatP	Obl	IntPP	SpP
24.2	23.7	14	8.6	7.2	6.6	2.5

Table 1: Relevance (%) of each type of grasp

Kinematic synergies were computed from the resulting data as the principal components (PCs) with eigenvalues higher than 1 in a Principal Component Analysis (normalized factors, varimax rotation), and their loading and variance explained were analysed.

Results

Hand kinematics required 6 PCs (synergies) to explain 73.3 % of the variance. Table 2 shows the different loadings of each joint for each synergy.

	Syn1	Syn 2	Syn 3	Syn 4	Syn 5	Syn 6
CMC1_F					**.81**	-.10
CMC1_A	-.21		-.23	.19	.23	**-.72**
MCP1			-.11		.17	**.86**
IP1		.22		**.71**		
PIP2	.27			**.80**	.15	
PIP3		**.89**				
PIP4	.15	**.90**	.11	.16		
PIP5	.32	**.74**	-.16	.26		
MCP2_F	.21		.11	.17	**.79**	.13
MCP3_F	**.80**			.38	-.10	
MCP4_F	**.74**	.21	**.47**	.16		
MCP5_F	**.85**	.28	**-.18**	.12		
MCP3-4_A	**-.65**			.17	-.19	
MCP4-5_A	-.22		**.81**		-.13	
PArch	-.10	.12	**-.74**		-.16	
Variance (%)	18.0	15.8	10.7	10.2	9.9	8.7

Table2: Loadings and variance for each synergy. Values < 0.1 have been suppressed and those > 0.4 are in bold.

Discussion

The first and second synergies found in this way are comparable to those described in previous studies [1], although with slight differences: they do not include the flexion of index finger. This result is novel and in accordance with recent studies describing the independence of the index finger and the thumb [5]. The remaining synergies mainly represent finer movements (such as palmar arch flexion, the coordination of the index and thumb joints and the individual control of the thumb). This result confirms the importance of the thumb and index finger during the performance of common grasps in ADL.

References

1. Santello et al., J Neurosci, 18:10105–15,1998
2. Gracia-Ibáñez et al., J Hand Ther, 31: 102-11, 2018
3. Atzori et al., Sci Data, 1:140053, 2014
4. Feix et al., Robotic, Sci & Sys Conference, 2009
5. Schieber et al., J Neurosci, 20(22):8542-50, 2000

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