Literature Introduction

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THE INTELLIGENT HAND

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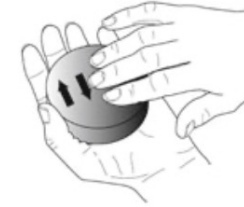
Susan J. Lederman

QUEEN'S UNIVERSITY
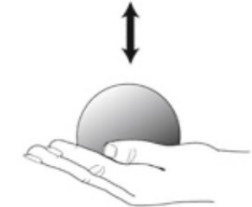KINGSTON, ONTARIO, CANADA K7L 3N6

- Introduces the concept of *Exploratory Procedures (EPs)*.

- Each EP is related to a particular object property.

Lateral Motion (Texture)
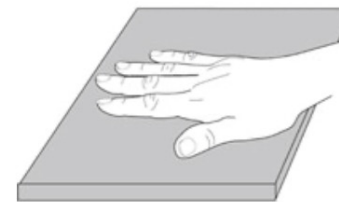
Unsupported Holding (Weight)
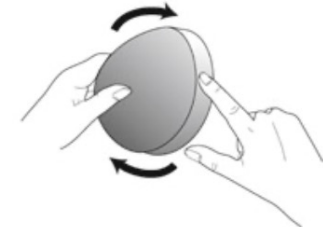
Pressure (Hardness)

Enclosure (Global Shape) (Volume)

Static Contact (Temperature)

Contour Following (Global Shape) (Exact Shape)

Review

Hand synergies: Integration of robotics and neuroscience for understanding the control of biological and artificial hands

Marco Santello [a,*], Matteo Bianchi [b,c], Marco Gabiccini [b,c,d], Emiliano Ricciardi [e,b], Gionata Salvietti [f], Domenico Prattichizzo [f,c], Marc Ernst [g], Alessandro Moscatelli [g,h], Henrik Jörntell [i], Astrid M.L. Kappers [j], Kostas Kyriakopoulos [k], Alin Albu-Schäffer [l], Claudio Castellini [l], Antonio Bicchi [b,c,**]

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[b] Research Center 'E. Piaggio', University of Pisa, Pisa, Italy
[c] Advanced Robotics Department, Istituto Italiano di Tecnologia (IIT), Genova, Italy
[d] Department of Civil and Industrial Engineering, University of Pisa, Pisa, Italy
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[f] Department of Information Engineering and Mathematics, University of Siena, Siena, Italy
[g] Department of Cognitive Neuroscience and CITEC, Bielefeld University, Bielefeld, Germany
[h] Department of Systems Medicine and Centre of Space Bio-Medicine, Università di Roma "Tor Vergata", 00173, Rome, Italy
[i] Neural Basis of Sensorimotor Control, Department of Experimental Medical Science, Lund University, Lund, Sweden
[j] Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands
[k] School of Mechanical Engineering, National Technical University of Athens, Greece
[l] DLR – German Aerospace Center, Institute of Robotics and Mechatronics, Oberpfaffenhofen, Germany

Hand synergies: motor control

- "Hand postures used to **grasp** a wide variety of **imagined** objects could be described by a very small number of linear combinations of joint angles, i.e. principal components or postural synergies (or *eigenpostures*)".

- "Lower-order principal components […] are mainly responsible for coarse hand opening and closing – and higher-order principal components corresponding to finer hand shape adjustments".

- "The apparent complexity associated with having to control multiple digit joints might be addressed by constraining them to move in a synergistic fashion. […] The problem of controlling many joints is not as complex as it seems".

Multidigit Movement Synergies of the Human Hand in an Unconstrained Haptic Exploration Task

Pramodsingh H. Thakur, Amy J. Bastian, and Steven S. Hsiao

Departments of Neuroscience, Neurology, and Biomedical Engineering, Zanvyl Krieger Mind/Brain Institute and Kennedy Krieger Institute, Johns Hopkins University, Baltimore, Maryland 21218

- 8 blinfolded subjects perform a haptic exploration task to identify fifty common objects using only one hand.
- For each subject they perform *Principal Component Analysis* and select the 10 eigenvectors corresponding to the 10 higher eigenvalues.
- "The 10 sets of hand postures corresponding to the 10 eigenvectors for each subject were visually compared across different subjects to identify similar trends. Those with similarities across multiple subjects were considered to belong to a common synergy".
- "Any posture can be considered as a unique point in this 9D space. Similarly, any exploratory movement can be considered as a trace or curve meandering inside this 9D space".

Postural changes along a synergy
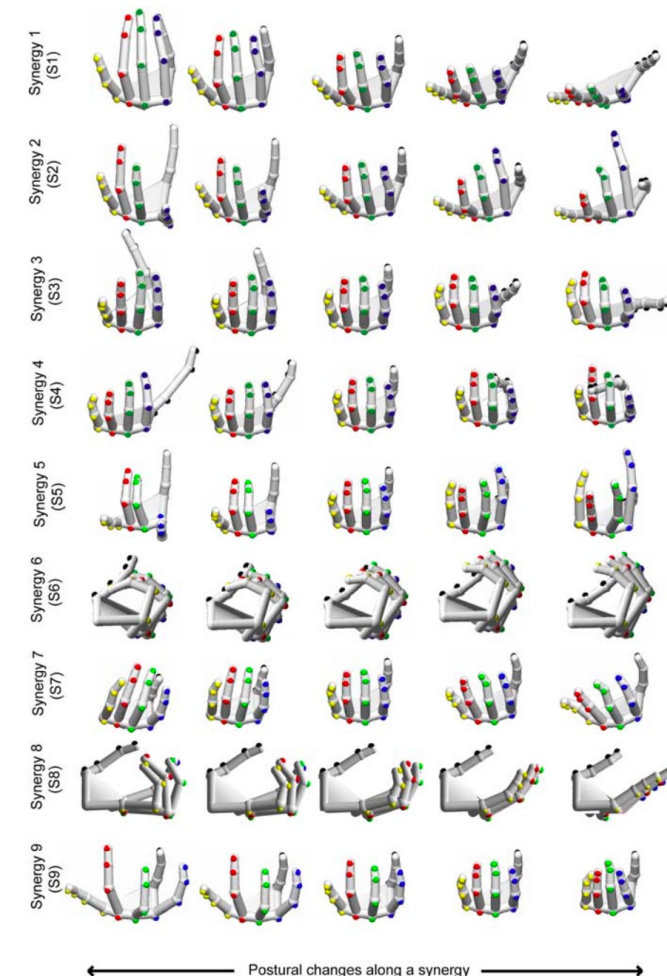
- "Any hand movement can be thought of as a combination of postural changes along contributing synergies. […] The synergies can be thought of as building blocks that contribute in varying proportions to construct any arbitrary hand movement patterns".

- "Because synergies combine in various ways to construct any continuous segment of hand motion, they can be thought of as building blocks of *Exploratory Procedures*".

- **Flaws:** Synergies are calculated for each subject and paired manually.

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and Rehabilitation
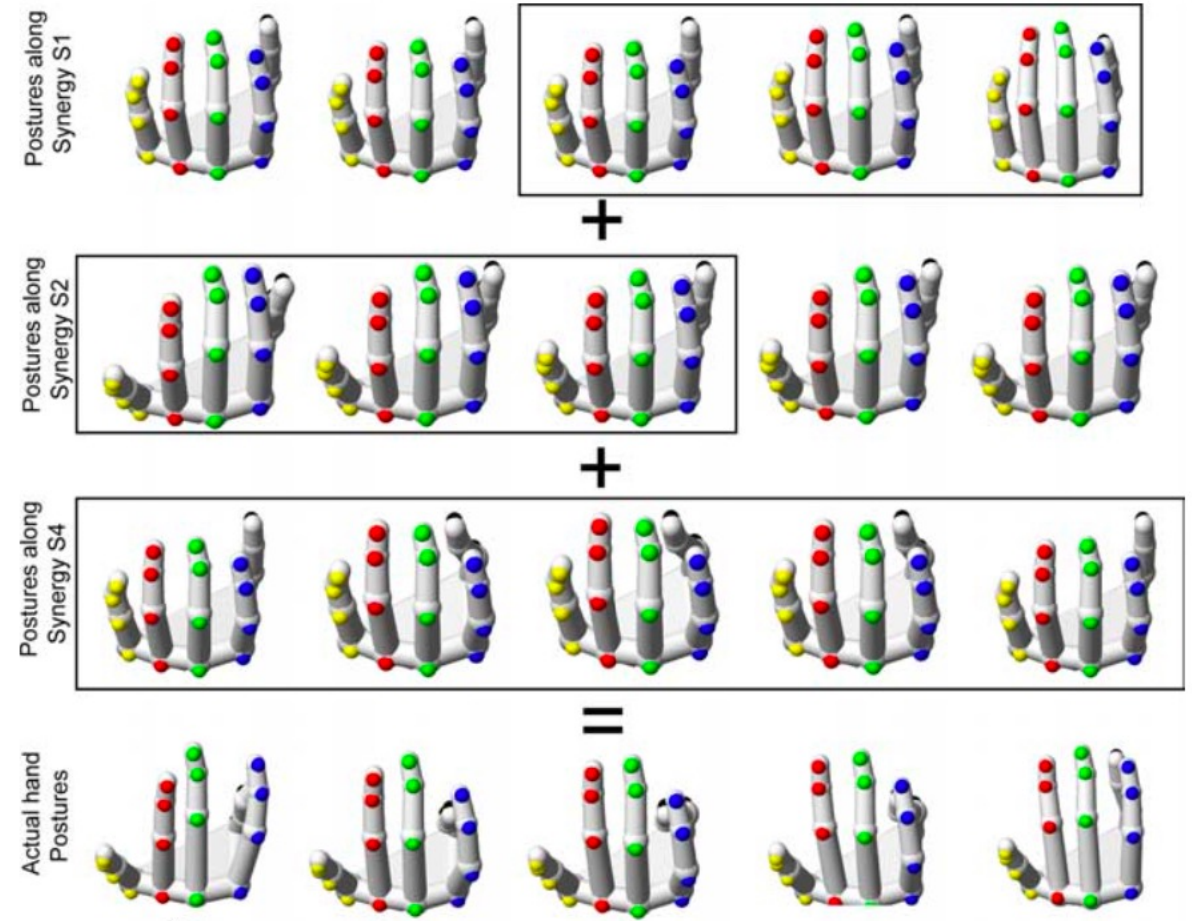
Kinematic synergies of hand grasps: a comprehensive study on a large publicly available dataset

Néstor J. Jarque-Bou[1], Alessandro Scano[2,3], Manfredo Atzori[4] and Henning Müller[4,5*]

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- Here synergies are also computed for each subject using *PCA*.

- Those synergies are grouped using a hierarchical cluster analysis.

- In this paper they compute hand synergies under two different conditions: with and without cutaneous (tactile) impairment.

- For the cutaneous impairment, participants were requested to wear rigid shels at their fingertips.

- They conclude that "the presence of tactile impairment, while modifying the strategies themselves, does not substantially modify the most basic kinematic ingredients commonly used to generate hand postures. [...] Cutaneous impairment affects posture refinement, which can be likeliy ascribed to higher order synergies".

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Postural Hand Synergies during Environmental Constraint Exploitation

Cosimo Della Santina[1]*, Matteo Bianchi[1], Giuseppe Averta[1,2], Simone Ciotti[1,2], Visar Arapi[1], Simone Fani[1,2], Edoardo Battaglia[1], Manuel Giuseppe Catalano[1,2], Marco Santello[3] and Antonio Bicchi[1,2]

[1]Centro E. Piaggio, University of Pisa, Pisa, Italy, [2]ADVR, Fondazione Istituto Italiano di Tecnologia, Genoa, Italy, [3]School of Biological and Health Systems Engineering, Ira A. Fulton Schools of Engineering, Arizona State University, Tempe, AZ, United States

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Muscle Synergy Analysis of a Hand-Grasp Dataset: A Limited Subset of Motor Modules May Underlie a Large Variety of Grasps

Alessandro Scano[1]*, Andrea Chiavenna[1], Lorenzo Molinari Tosatti[1], Henning Müller[2] and Manfredo Atzori[2]

[1] *Institute of Intelligent Industrial Technologies and Systems for Advanced Manufacturing (STIIMA), Italian National Research Council (CNR), Milan, Italy,* [2] *Information Systems Institute, University of Applied Sciences Western Switzerland (HES-SO), Sierre, Switzerland*

- Authors extract muscle synergies from sEMG data using *non-negative matrix factorization (NMF)*.

- *They group the synergies using* k-means *clustering algorithm.*