# HANDS.DVI

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# Grippers and hands

Why Buy a BarrettHand™ when Parallel-Jaw Grippers are so Cheap?

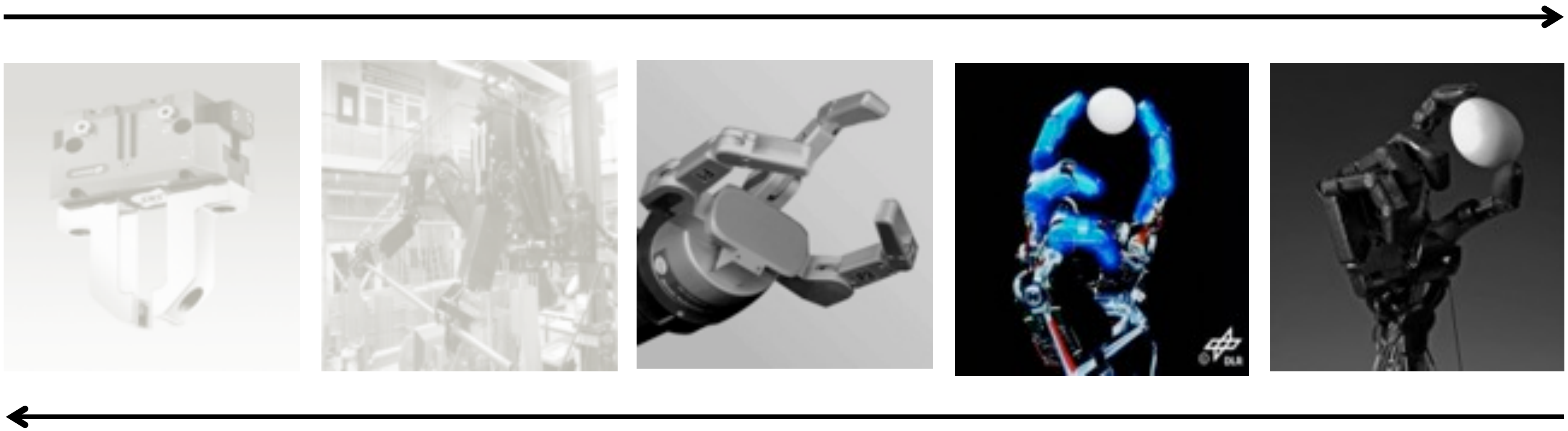
1) Each gripper must be <u>custom designed</u>. Grippers require specialists to design, fabricate, and debug <u>specially-shaped finger surfaces</u> for each part shape and for each unique part orientation.

2) Unless the host arm will perpetually perform the same task, it needs <u>an infinitely variable supply of grippers</u> and the ability to switch between them instantly as the part shapes and orientations change. <u>A robot arm exchanges grippers with either a turret or a tool changer. A turret is limited to switching between 2 or 3 grippers</u>. A tool changer can handle a large number of grippers, but at the enormous costs of wasted space from storage fixtures and badly increased cycle times.

Combined with its versatile software routines, <u>a single BarrettHand matches the functionality of an endless set of custom grippers</u> -- yet switches part/tool shapes electronically within half a second. [Courtesy of Barrett Technology Inc.]

# The problem

N. of DoFs



N. of app. in industries

Why articulated hands are not so frequently used in industrial environments ?
- Too complex from a control point of view: reaching, grasping, manipulation
- They suffer from a lack of standard <u>control approaches</u>

Robotic hands are crucial for exploiting robotics in flexible industrial scenarios

# The problem

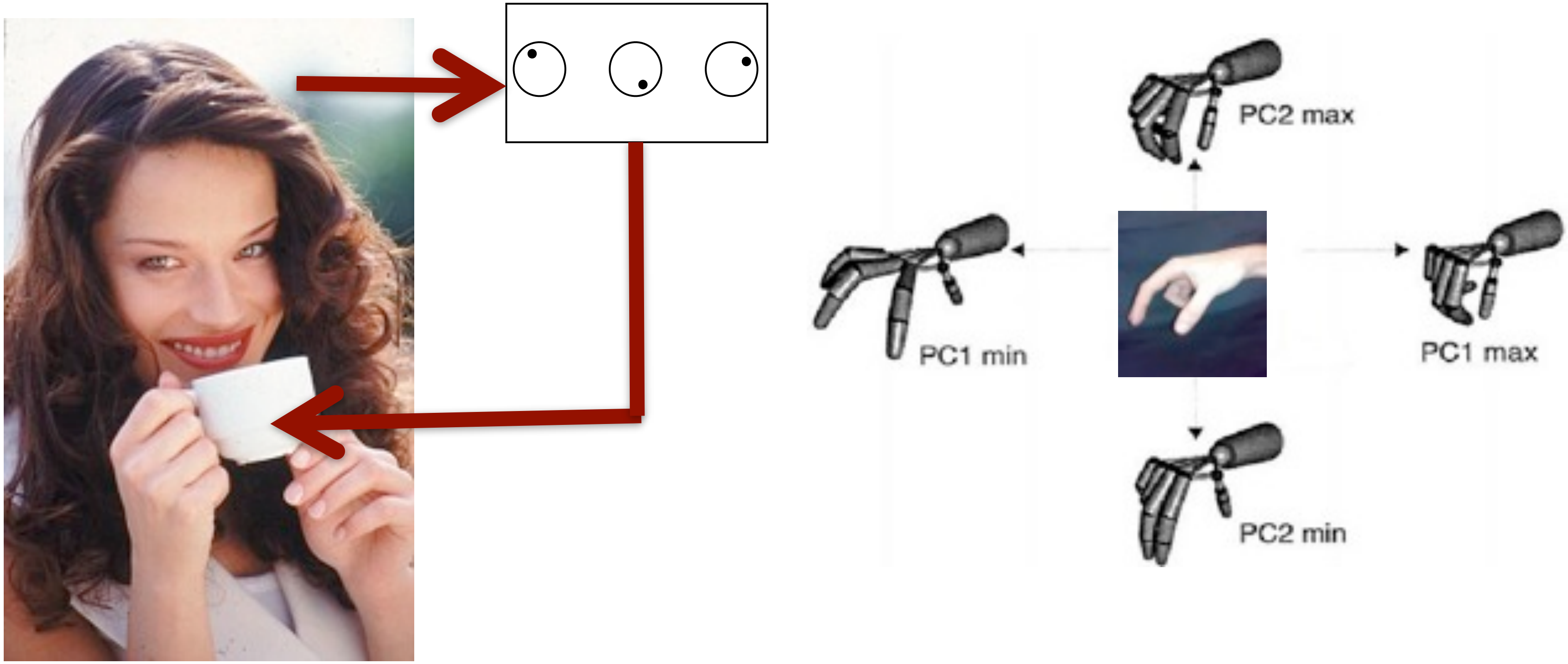
N. of DoFs

N. of app. in industries

Because of their intrinsic complexity, there is not a standard approach to the control of grasping and manipulation tasks. Borrowing the terminology of software engineering, there is a need for middleware solutions for manipulation and grasping tasks to seamlessly integrate robotic hands in flexible cells.

Cooperation with robotic hand manufacturers (control driver design and tests).

# Inspired by sensorimotor synergies




Human-like dexterous manipulation.

# Postural synergies

Santello et al. [1998, 2002] investigated the hypothesis that "learning to select appropriate grasps is applied to a series of inner representations of the hand of increasing complexity, which varies with experience and degree of accuracy required."


- $5$ subjects were asked to shape their hands in order to mime grasps for a large set $(57)$ of familiar objects
- Joint values were recorded with a CyberGlove;
- Principal Components Analysis (PCA) of these data revealed that the first two Principal Components or postural synergies account for $\sim 84\%$ of the variance, first three $\sim 90\%$
- PCs (eigenvectors $S_i$ of the Covariance Matrix) can be used to define a basis for a subspace of the joint space

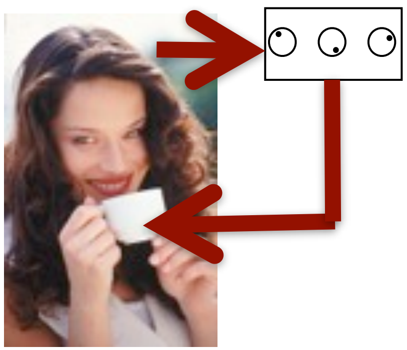
# Synergistic motions $q(t) = Sz(t)$

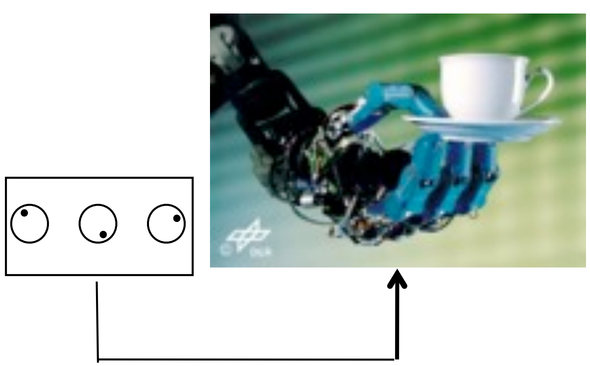
$$S = \begin{bmatrix} \vdots & \vdots & \vdots & \vdots & \dots & \vdots \end{bmatrix} \in \mathbb{R}^{20\times 20}$$

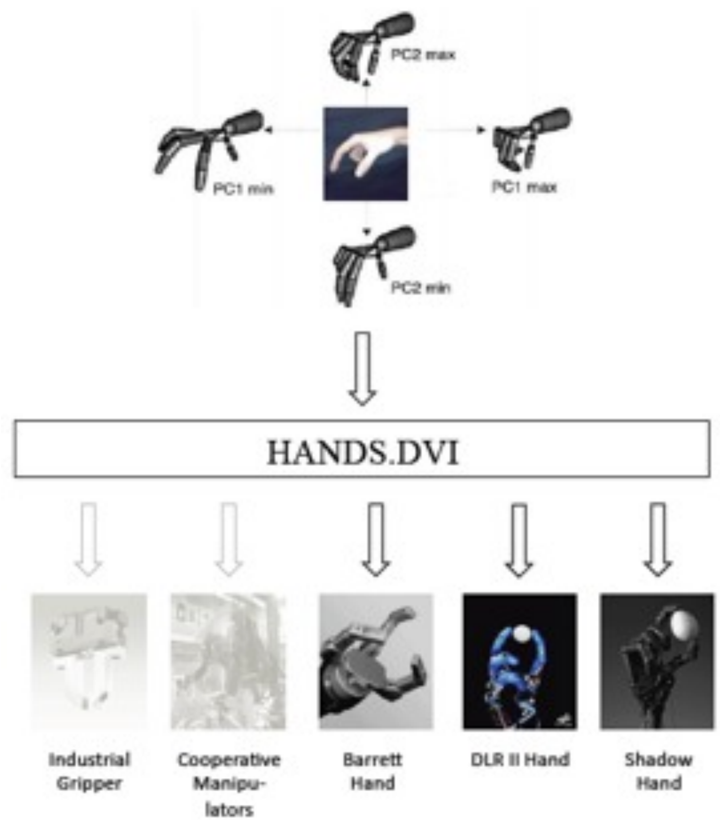
The first three components, i.e. columns $S_1, S_2$ and $S_3$ account for the $90\%$ of the data.

$q = S_1 z_1$ $\qquad\qquad$ $q = S_2 z_2$ $\qquad\qquad$ $q = S_3 z_3$

# A few knobs for the abstraction layer







# The main points

The paradigmatic hand

``A trade–off between the complexity of the human hand model accounting for the synergistic organization of the sensorimotor system and the simplicity of the models of robotic hands available on the market.“

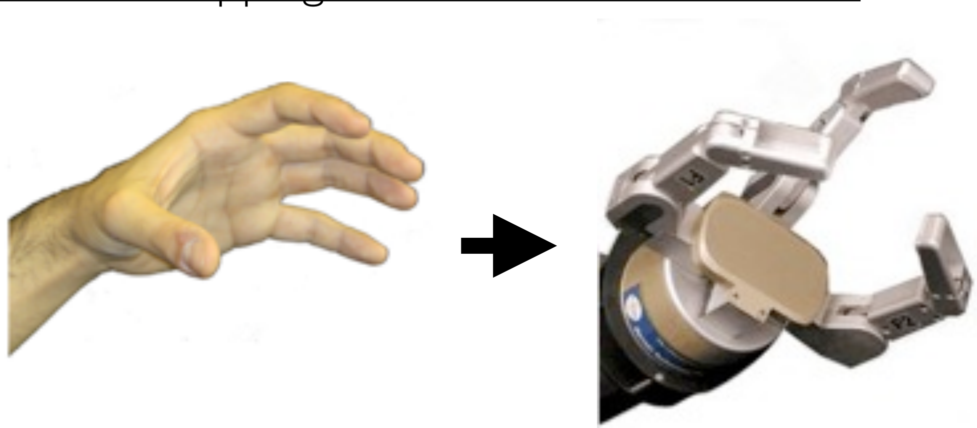
Synergies

``The paradigmatic hand will be developed to define a basis of synergies that will allow to design simplified strategies for the control of grasping forces. Here, the number and the structures of the force synergies will be defined.’’

Projecting synergies to the robotic hands with dissimilar kinematics

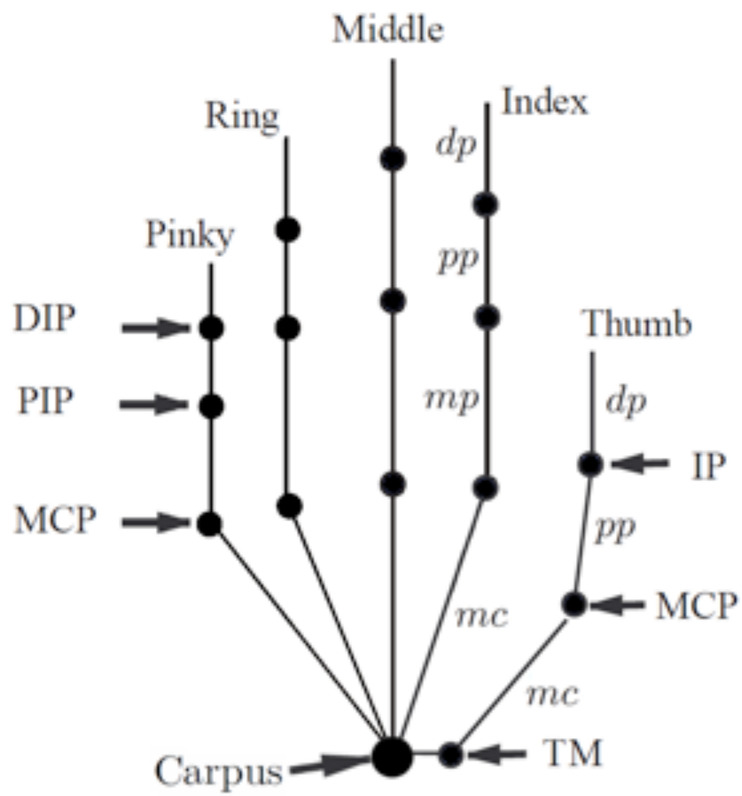
``Theoretical tools to design a suitable mapping function of the control action (decomposed in its elemental action, synergies) from the paradigmatic hand domain onto the articulated hand co-domain.

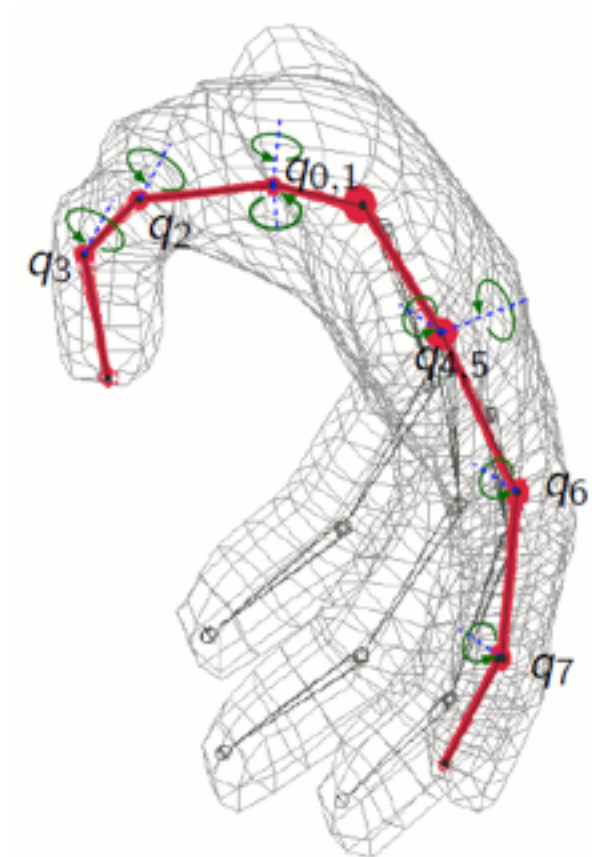
The definition of this mapping is the core of HANDS.DVI.



# The paradigmatic hand with synergies

- Kinematic model of the hand

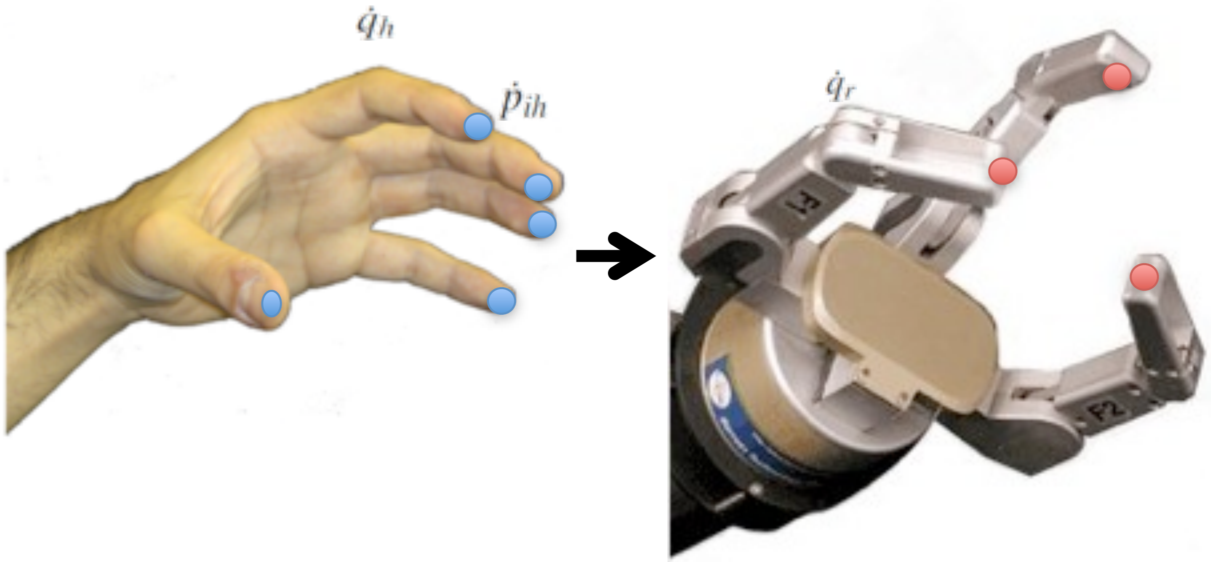


# Different mapping approaches

- **Joint-to-joint mapping**: joint values of human hands directly mapped into robotic joints. Empirical solutions for non-anthropomorphic hands. [M. T. Ciocarlie, P. K. Allen – 2009, Ficuciello et al. 2011]

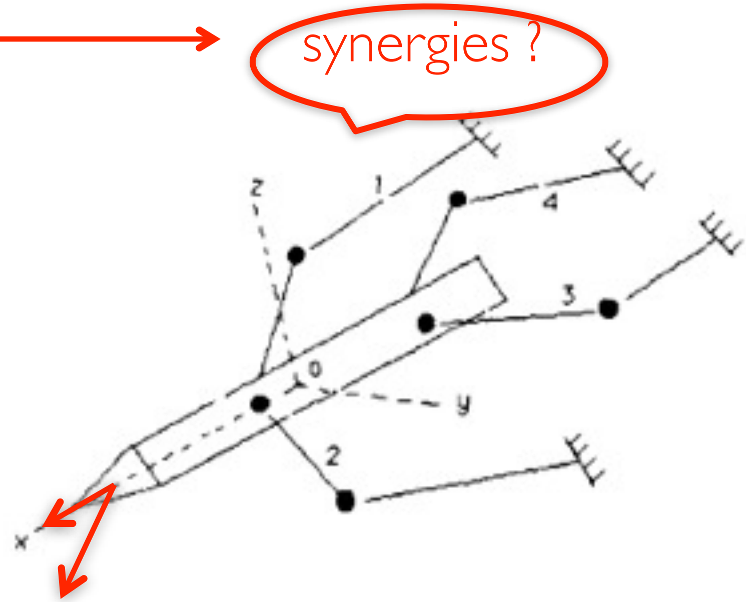
- **Fingertip mapping**: relation between different workspaces. [A. Peer, S. Einenkel, M. Buss – 2008]



# Object-space mapping for forces and motions

Middleware


Real hand

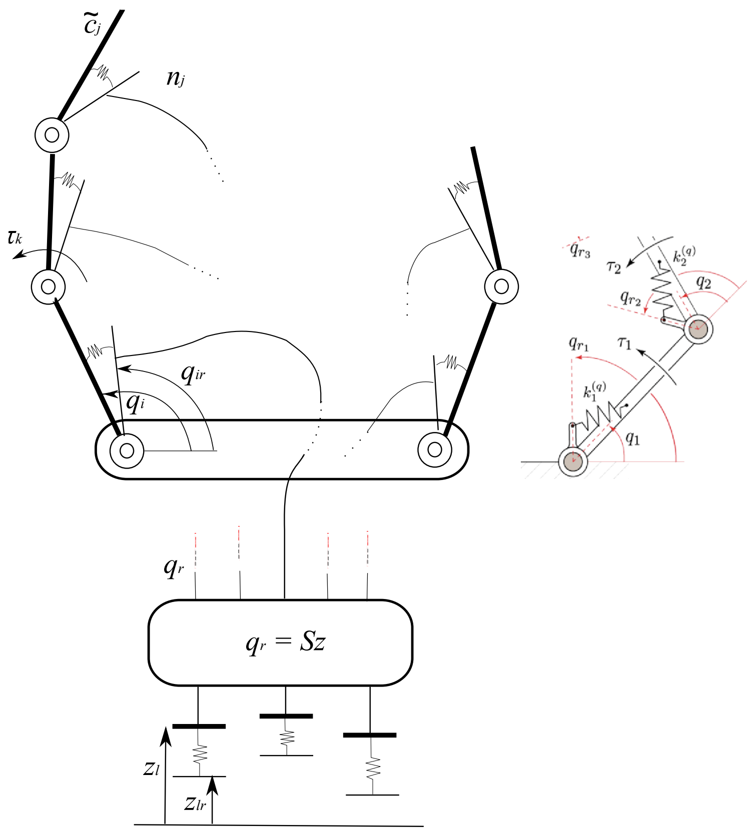



object-oriented.

- compute the object motion associated to synergies in the paradigmatic space
- assign those ellipsoid to the same object but with the real hand
- solving an inversion problem compute the synergy mapping

A synergy mapping for a given object and a given set of contacts.

# The Soft-Synergies Model



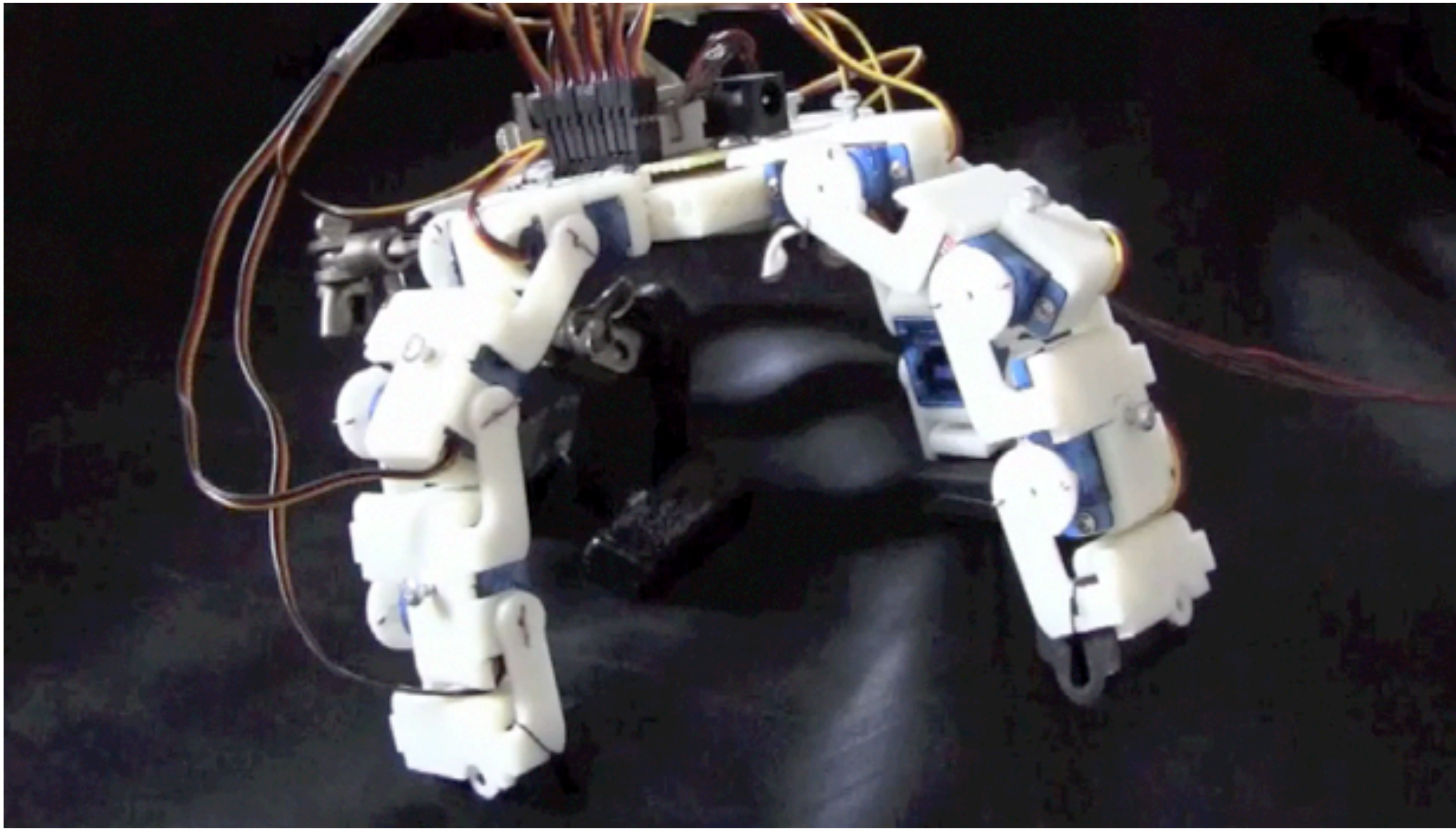

- The hand is actuated using a number of inputs whose dimension is lower than the number of hand joint and we define it as *synergies*.
- We define the synergies as a joint displacement aggregation corresponding to a reduced dimension representation of hand movements according to a compliant model of joint torques.
- The reference vector $q_r$ for joint variables is a linear function of *postural synergies* $z \in \Re^{n_z}$ with $n_z \leq n_q$

$$q_r = Sz$$

through the *synergy matrix* $S \in \Re^{n_q \times n_z}$.

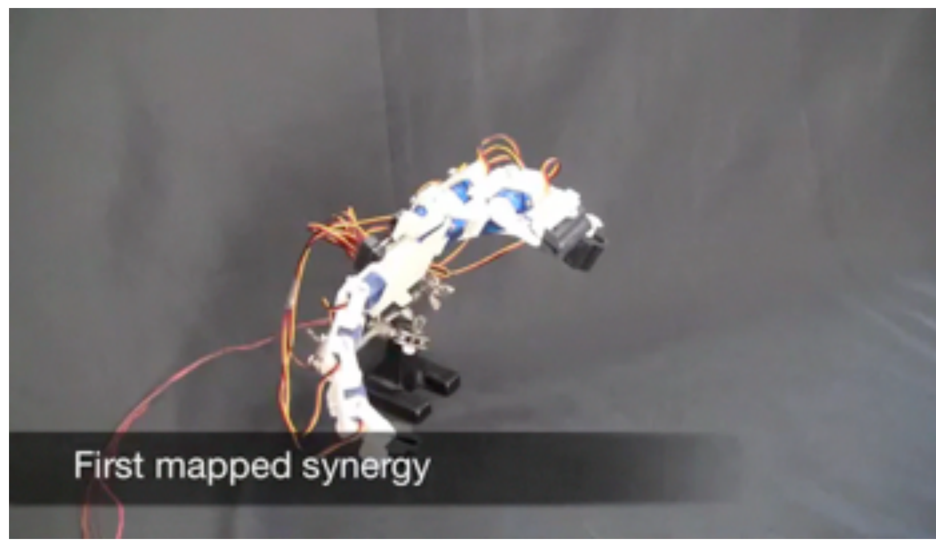
[Prattichizzo, Malvezzi, Bicchi, RSS 2010]

# The modular hand

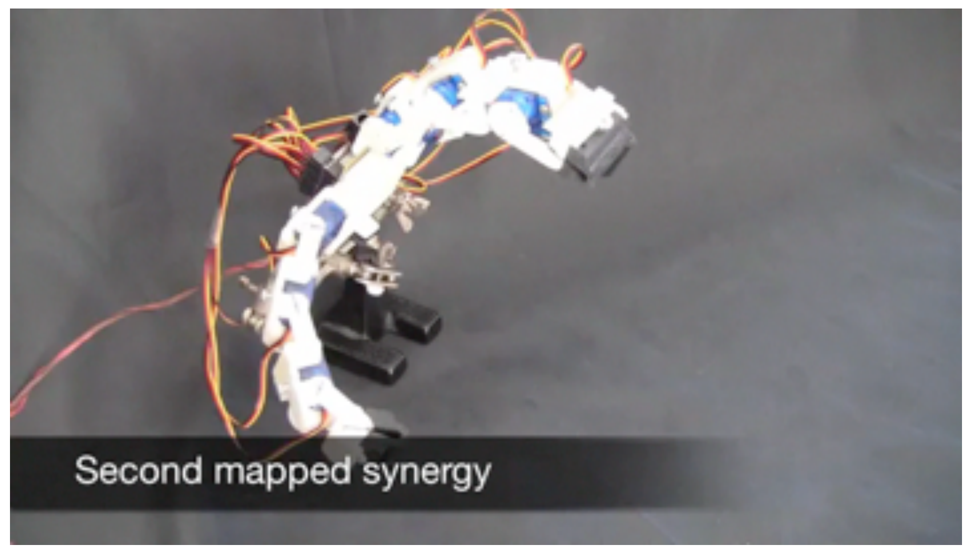


9 joints, (DoF) | 9 motors, | only 4 synergies (Degree of Control)

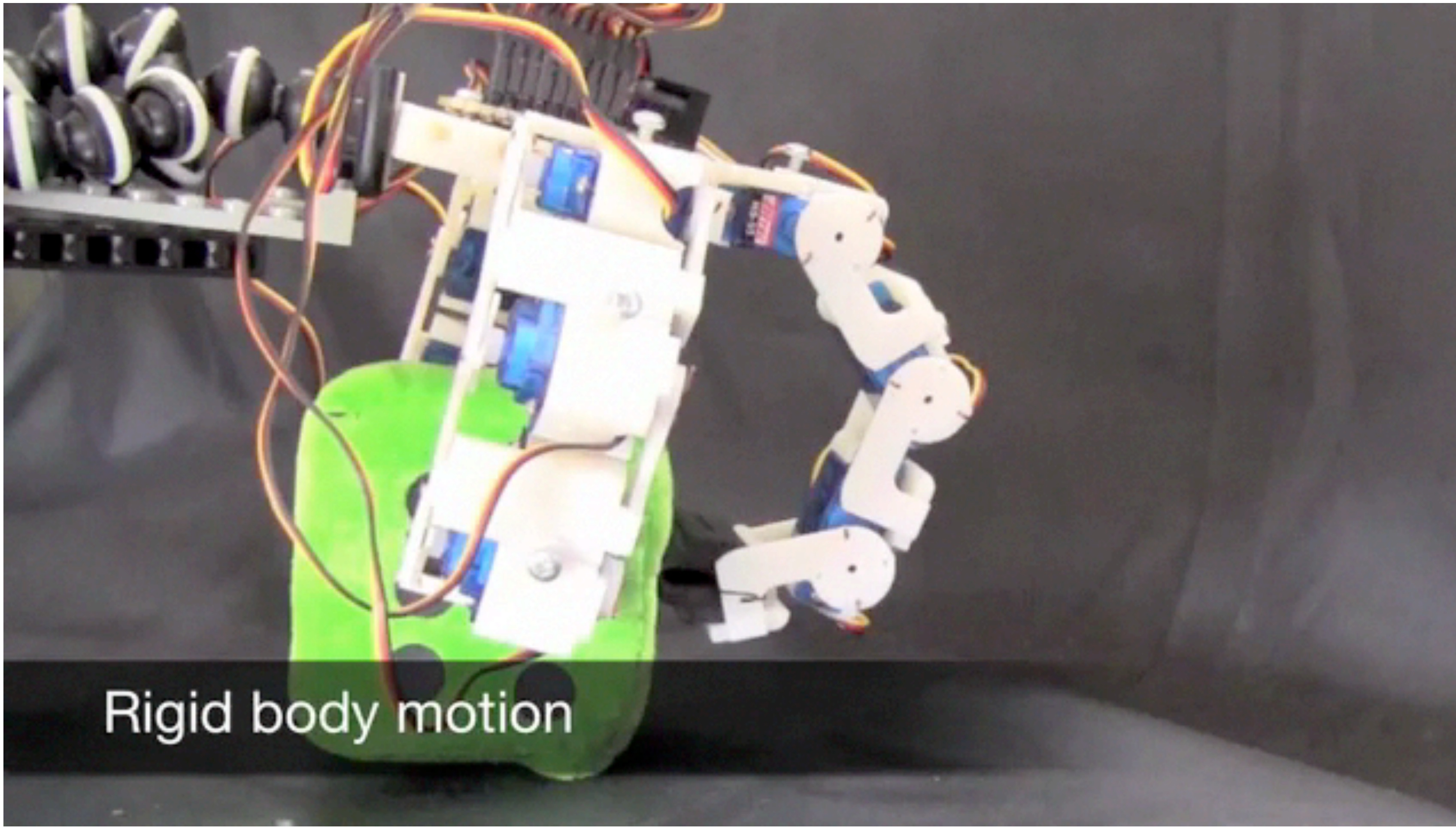
# The first three mapped synergies



# The first three mapped synergies

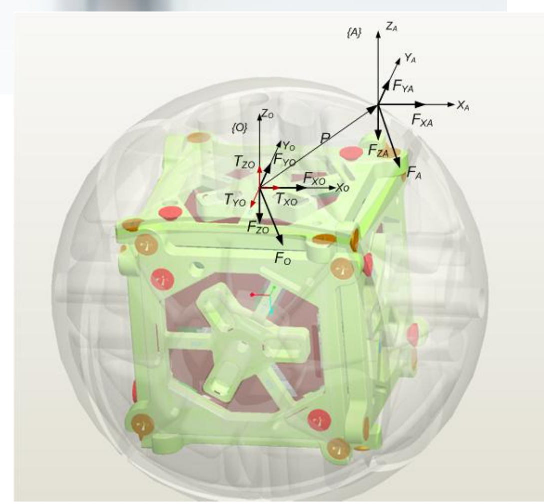


# Controlling the object motion




| | internal forces | rigid-body motion |
|---|---|---|
| synergies (4 inputs) | 3 | 1 |

# More robotic hands


- more complex tasks

# Remarks

N. of DoFs





N. of apps in industries

- An abstraction layer or control driver to simplify the control of robotic hands.
    - more seen as grippers or graspers
- Solve the manipulation task problem in the human-like hand domain
    - Trust on local control laws based on tactile reactive feedback
- Work on contact standardization between object and robotic hands

- Cooperation with robotic hand manufacturers (control driver design and tests)