Efficient Modular Grasping: an Iterative Approach

F. Sanfilippo, G. Salvietti, H.X. Zhang, H.P. Hildre and D. Prattichizzo

Department of Marine Technology and Operations,
Aalesund University College

and

Department of Information Engineering,
University of Siena

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Summary

Bio-inspired Robots, challenges

Mimicking the human hand's ability, one of the most challenging problem in bio-inspired robotics

- large gap between the performance of anthropomorphic robot hands and human hands
- building a robotic hand with sufficient dexterity
- large number of degrees of freedom

A possible solution

- minimum number of degrees of freedom necessary to accomplish the desired task

Bio-inspired Robots, possible approaches

Classical approach: analysis of the kinematic behavior of the human hand

- simplified human hand models with minimum and optimal degrees of freedom, Cobos et al.[1]
- efficient manipulation tasks

Classical approach: main disadvantage

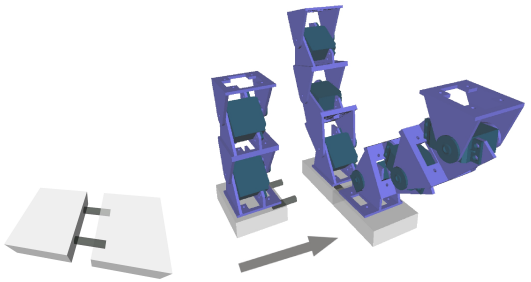
Such simplified robotic hands are usually difficult to adapt to different grasping operations or to the grasping of objects with dissimilar size

Modular approach

A promising approach to get such flexibility

[1] S. Cobos Guzmán, M. Ferre Perez, and R. Aracil Santonja, "*Simplified human hand models based on grasping analysis*", 2010.

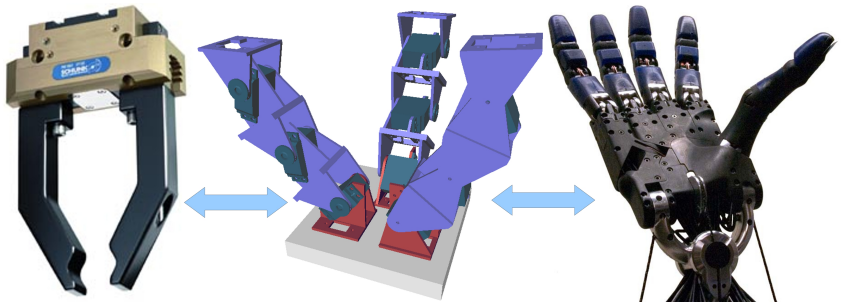
Main Idea and Goal



- A trade off between a simple gripper and more complex human like manipulators
- *Principle of minimalism*: choose the simplest mechanical structure, the minimum number of actuators, the simplest set of sensors, etc.

Modular grasping

Identical modules are used to build linkages in order to realize the grasping functions. From a mechanical point of view, even if it is not the most efficient grasping approach, the modular grasping still meets the requirements of standardization, modularization, extendibility and low cost

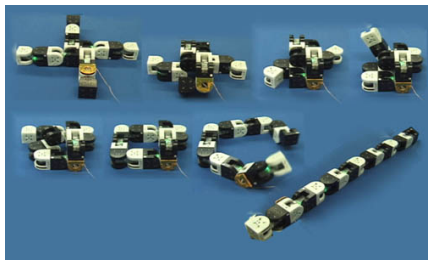


History and State of the Art

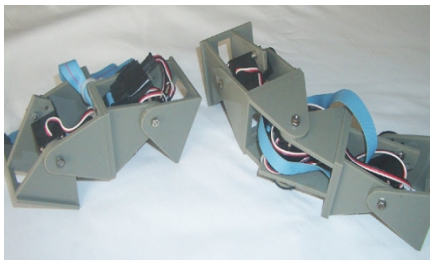
- simple actuated units;
- additional specialized units such as grippers, feet, wheels, cameras, ...

System	Class, DOF	Author	Year
PolyBot	chain, 1 3D	Yim et al. (PARC)	1998
Atron	lattice, 1 3D	Stoy et al., (U.S Denmark)	2003
Superbot	hybrid, 3 3D	Shen et al., (USC/ISI)	2004
M-TRAN III	hybrid, 2 3D	Kurokawa et al., (AIST)	2005
Y1 Modules	Chain, 1 3D	Zhang & Gonzalez-Gomez (TAMS, UAM)	2004


Atron


M-TRAN III


Miche


Y1

The Model

Human-like design

- one or more chains of modules fixed on a base
- each chain can be considered as a finger, each module as a phalanges and the base as a palm
- each finger is attached on its own base plate module

Three possible modular base configurations

- linear base
- circular base
- opposable-fingers base

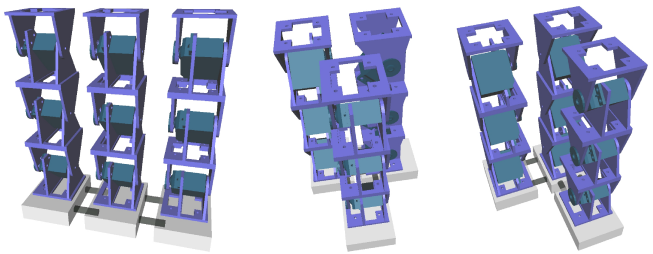


Figure: Possible base configurations for a three fingers modular device: *no finger opposition* (a), *circular* (b) and 1-*opposable-thumbs* (c).

Modular Gripper Design Algorithm. Flow-chart

$m(i)$	Current num. of modules
M	Maximum num. of mod. per finger
$f_{min}(i)$	Minimum num. of fingers
$Q_{desired}$	Predefined desired grasp quality

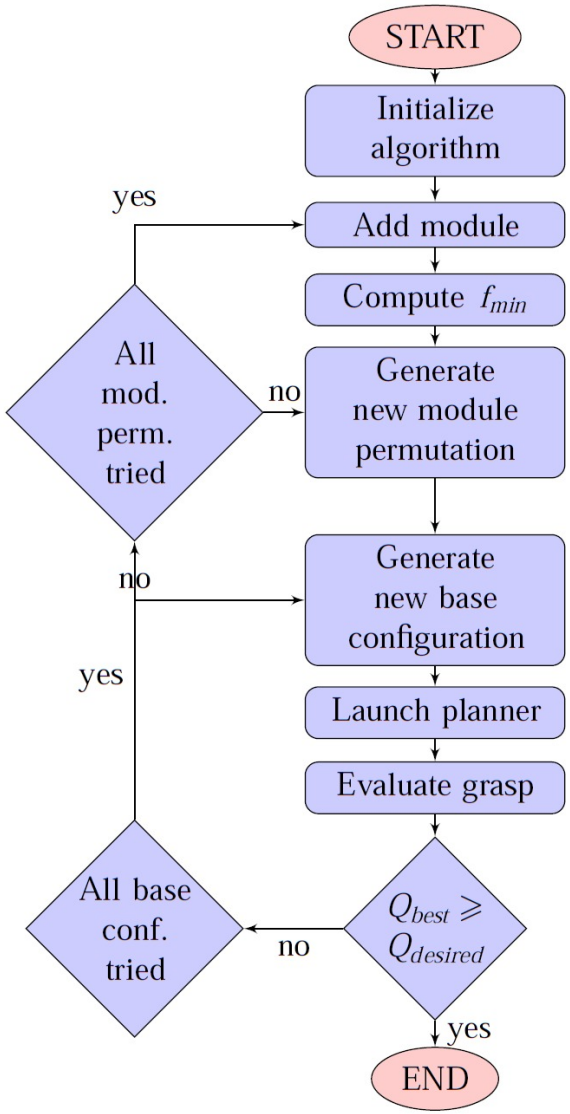
$$M_{min} = \left\lceil \frac{R}{L} \right\rceil, M_{max} = \left\lfloor \frac{2\tau_{max}}{Lw} \right\rfloor. \quad (1)$$

Compute f_{min}.

$$\frac{m(i)}{f_{min}(i)} \leqslant M. \quad (2)$$

If the inequality is not satisfied, f_{min} is incremented by one to avoid the insertion of more than M modules into a finger.

Launch planner. A grasp planner is used in order to determine the grasps achievable with the current configuration (forward solution implemented in "Openrave").



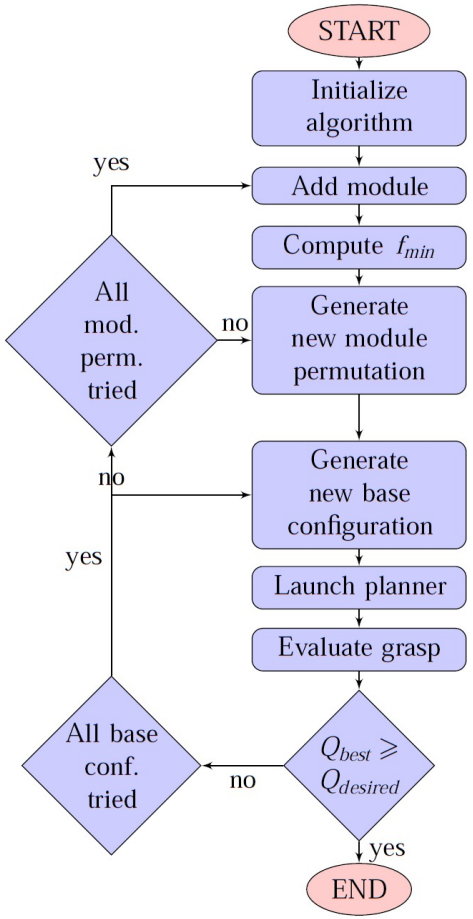
Modular Gripper Design Algorithm. Flow-chart

Evaluate grasp. Quality criteria introduced by Ferrari and Canny [1].

In particular we used $Q1$, that is the radius of the largest inscribed sphere centered at the origin contained in the GWS.

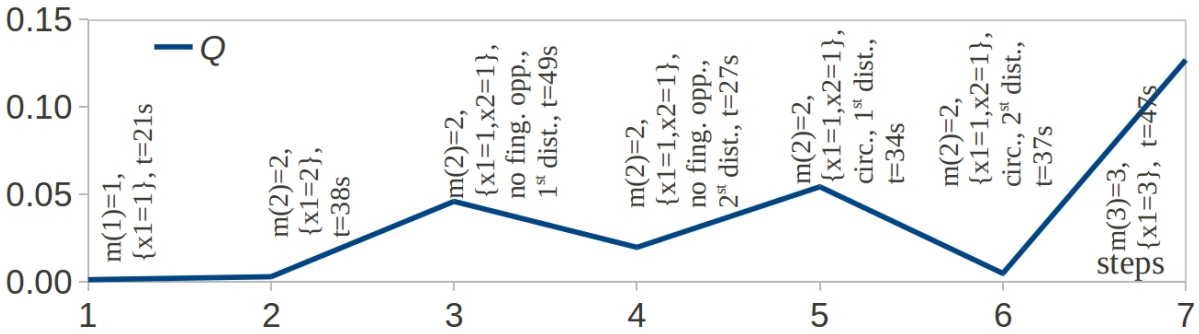
$$GWS = ConvexHull\left(\bigcup_{i=1}^{n} \{w_{i,1}, \ldots, w_{i,k}\}\right)$$

However, all the other solutions could be implemented and used in our algorithm.

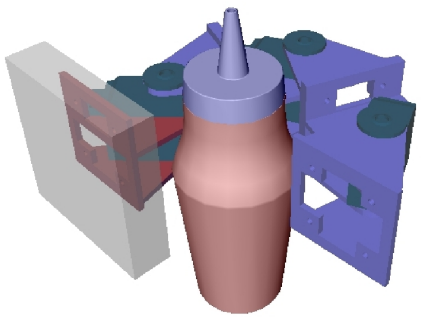


[1] Ferrari, C., and Canny, J. "*Planning optimal grasps*". In Robotics and Automation, 1992. Proceedings., 1992 IEEE International Conference on (1992), IEEE, pp. 2290-2295.

Grasping a Ketchup Bottle



(a)



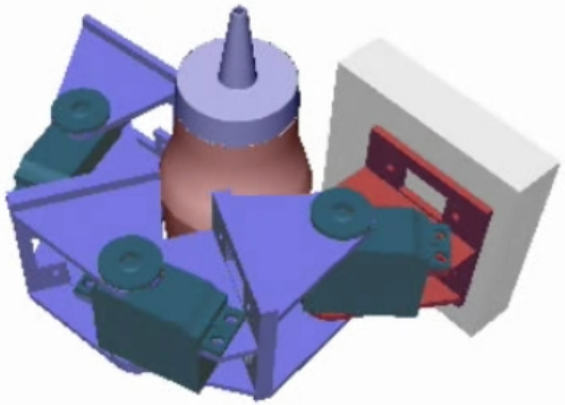
(b)

Figure: Steps of the algorithm (a) and effective configuration (b) for grasping a bottle of ketchup.

We chose $Q_{desired} = 0.1$ since this or a greater measure of quality corresponds to grasps that a human would consider "stable".

Grasping a Ketchup Bottle. Simulation

Q1 = 0.1270 > 0.1
Q2 = 0.1127
planner execution time = 47 s
m = 3, f = 1



Grasping Other Objects or Sets of Objects

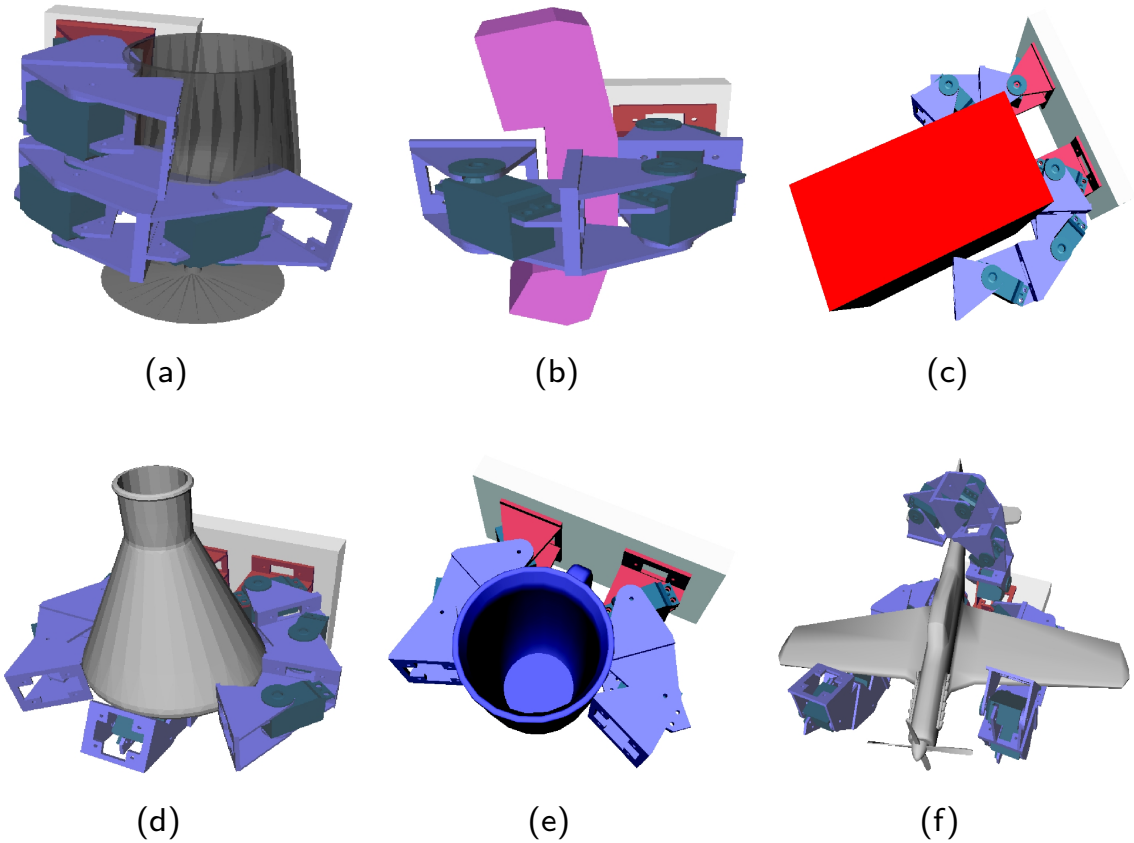


Figure: Minimum manipulator configurations for respectively grasping a glass (a), a phone (b), a book (c), a flask (d), a cup (e) and an aircraft model (f).

Conclusion and Future Work

Achievements

- a novel algorithm that determines effective modular configurations to get efficient grasps of given objects
- the resulting modular configurations are able to perform effective grasps that a human would consider "stable"

Problems

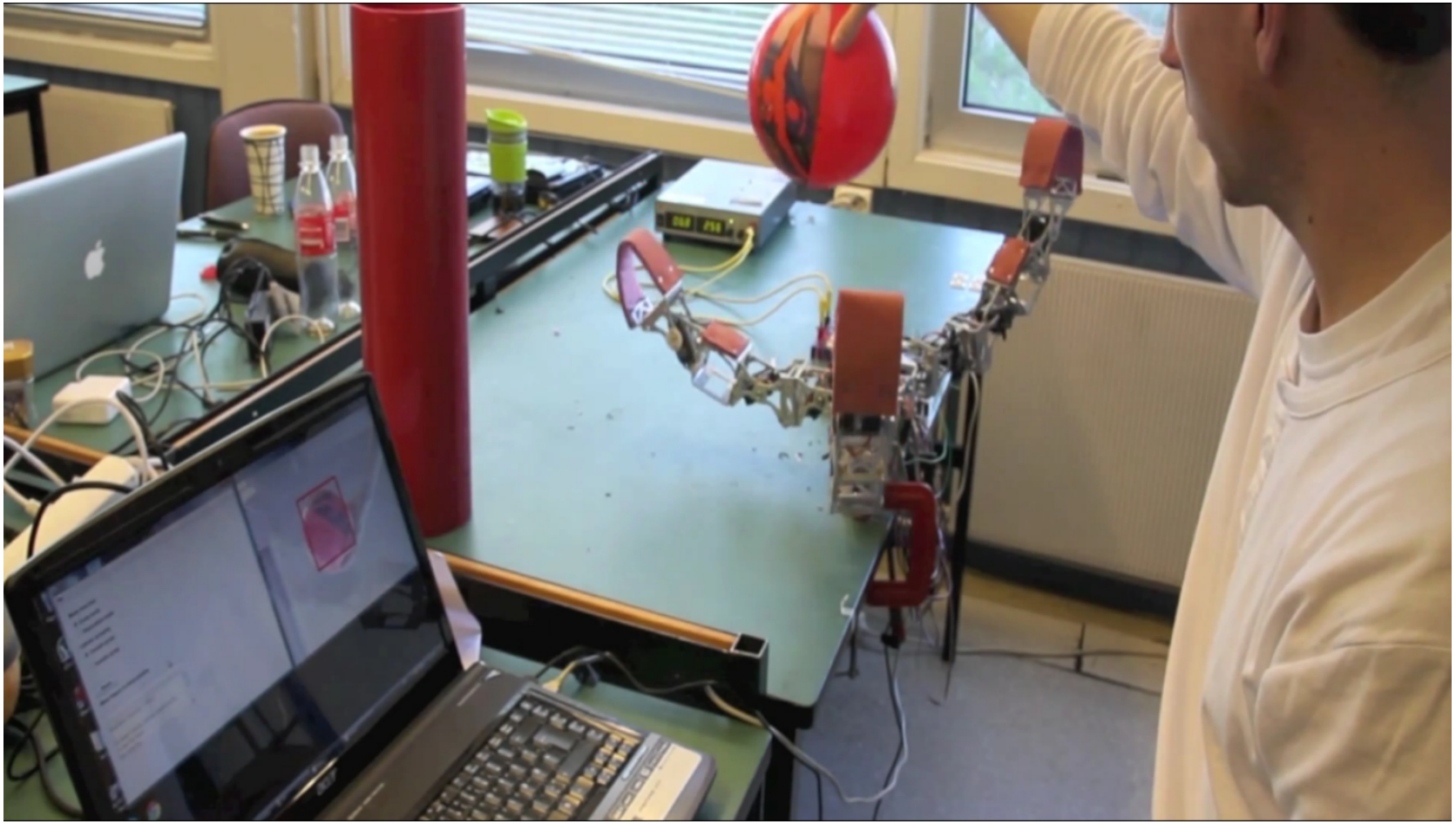
- complexity of the algorithm

Future Work: Task-oriented Grasping

- we should also take into account the re-usability of a grasped object
- only the grasp evaluation phase has to be modified in order to use a task-oriented metrics [1]
- real implemantation on the way

[1] J. Aleotti and S. Caselli. "*Grasp programming by demonstration: A taskbased quality measure*". In Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on, pages 383-388. IEEE, 2008.

Real Implemantation on the way



Thank you for your attention