On the Design of Effective Modular Reconfigurable Grippers: an Iterative Approach

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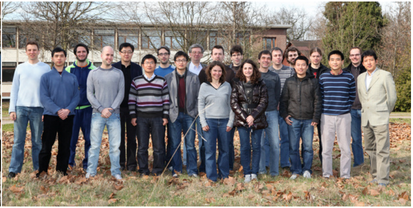
Academic year 2009/2010

University of Siena

April 29th,2011

A collaboration between SIRSLab and TAMS Group

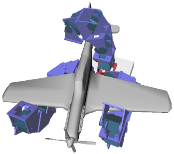
Università di Siena

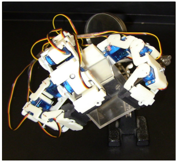


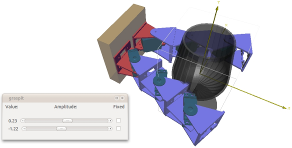
University of Hamburg

Main Contributions

- An algorithm capable of determining efficient modular gripper configurations to get a stable grasp of given objects;
- two real grippers obtained using the design algorithm;
- a simple planar manipulator model controlled drawing inspiration from the concept of human postural synergies.







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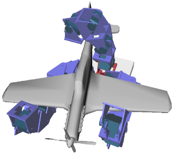

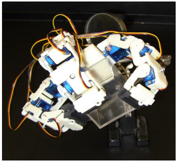

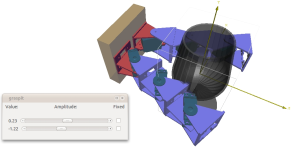

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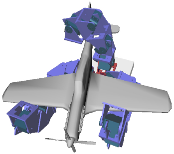
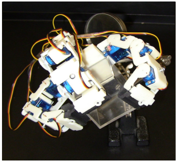
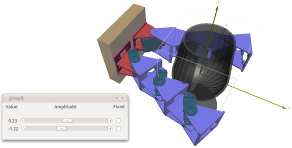
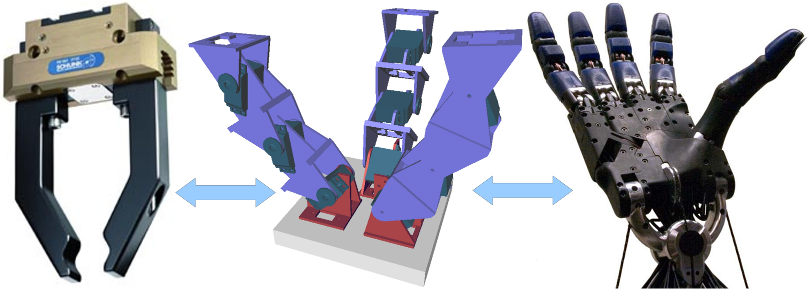






Main Idea and Goal



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
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GZ-I Modules	Chain, 1 3D	Zhang & Gonzalez-Gomez (TAMS, UAM)	2006


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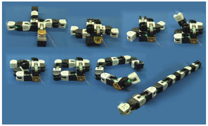
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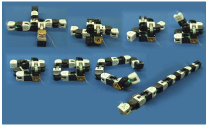
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Previous Research on Modular Robot Design

There are many studies on kinematics, dynamic, and control design of modular robots.

Three levels of modular robot architecture can be recognized:

- Module-level;
- Assembly-level;
- Configuration-level.

Our approach

We propose a new algorithm that involves all the three levels of modular robot architecture.

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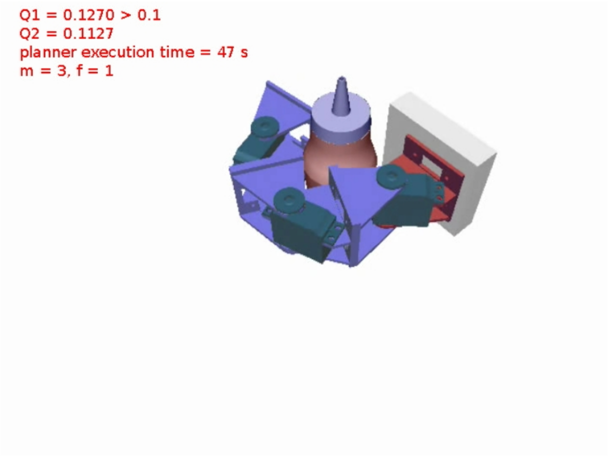
Modular Gripper Design Algorithm. The Idea



Modular Gripper Design Algorithm. Flow-chart

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

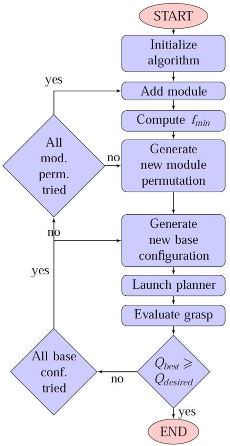
Compute f_{min}.

$$\frac{m}{f_{min}} \leqslant M. \quad (1)$$

If the inequality is not satisfied, f_{min} is incremented by one to avoid the insertion of more than M modules into a finger.
Base configurations. We defined three kinds of *base dispositions*:

- *no finger opposition base*;
- *circular base*;
- *i-opposable-thumbs base*.

We also considered the possibility to change the distance between the slots where the fingers are placed on the base.



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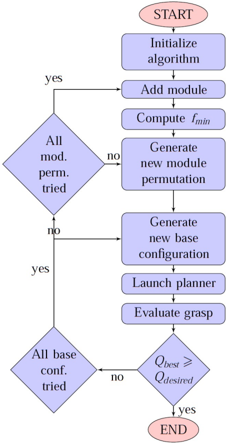

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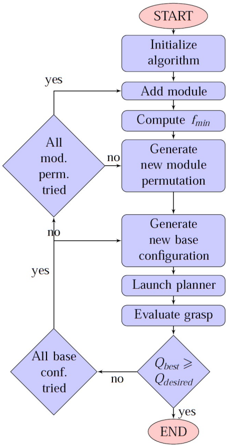


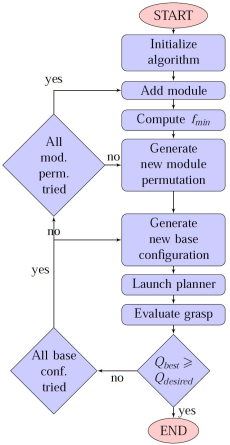
Modular Gripper Design Algorithm. Flow-chart

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

Evaluate grasp. In literature, there are different methods for assessing the grasp quality. We used the quality criteria introduced by Ferrari and Canny [1]. However, all the other solutions could be implemented and used in our algorithm.

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

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



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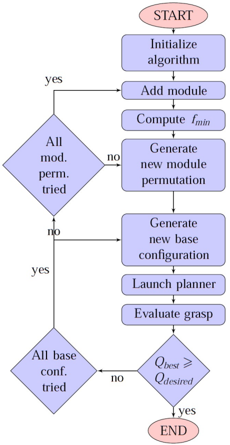

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Grasping a Ketchup Bottle

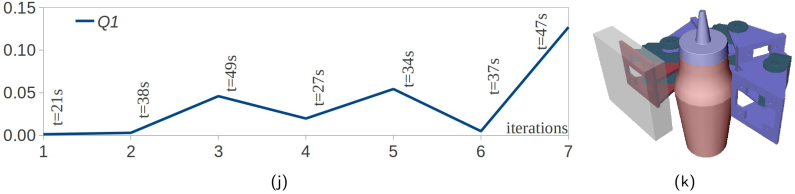
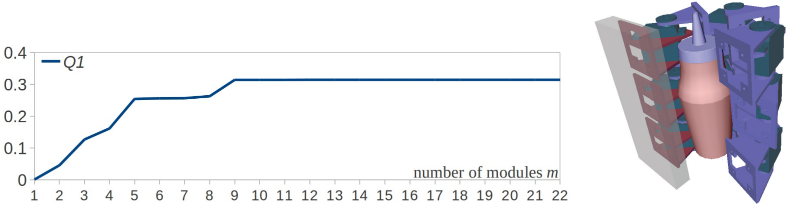


Figure: Steps of the algorithm (a) and effective configuration (b) for grasping a bottle of ketchup.

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

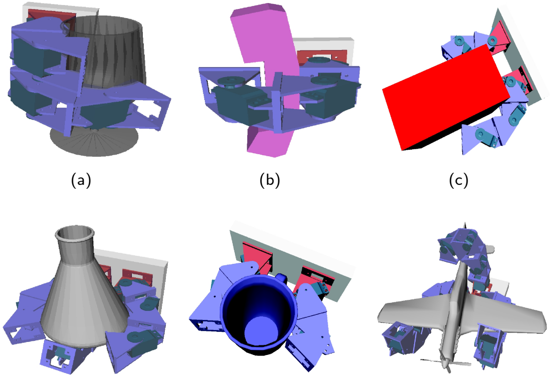
Best Achievable Configuration



(a) (b)

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

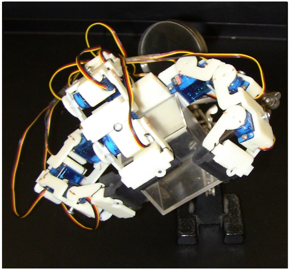
Grasping Other Objects or Sets of Objects



(a) (b) (c) (d) (e) (f)

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).

A Real Implementation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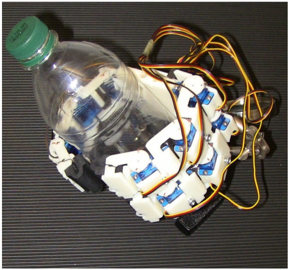
(b)

Figure: Gripper configurations for cubic (a) and cylindrical (b) objects.

Human Postural Synergies and Modular Grippers

- Despite the simplicity of a modular manipulator model, with the increase in the number of its fingers and modules, it also becomes rival to the human hand in complexity.
- Modular manipulators can be very different from the human one.
- We explored the possibility of using the two dominant human pregrasp shapes [1] called *eigengrasps* [2] in order to control one of the gripper obtained using our design algorithm. While we found our choices to produce good results, the optimal choice of eigengrasps for non-human hands, as well as the choice of which eigengrasps to use for a particular task, are still open questions.

Figure: The two dominant human eigengrasps.

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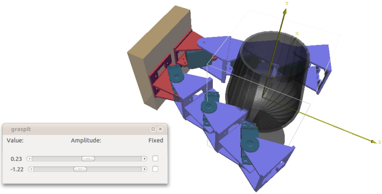
A Possible Gripper Model



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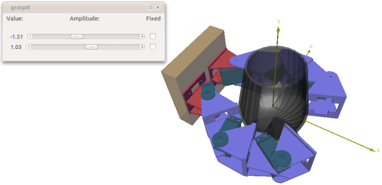

(b)

Figure: Grasp of a glass performed using the proximal joints flexion (a) and the distal joints flexion eigengrasp (b) objects.

Conclusion

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Problems:

- complexity of the algorithm;
- nor task-oriented neither hand-oriented approach.

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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 metric [1].

Hand-oriented Grasping

- At each iteration, once the current manipulator configuration is generated, the achievable eigengrasps have to be defined;
- A method for obtaining the optimal choice and mapping of human synergies for non-human hands is necessary;
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Thank you for your attention

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I thank all my family, especially Mom and Dad. Thank you for your care, support and incomparable love. I am who I am, because of you. Thanks also to my sister Elisa and my brother Riccardo for having always been close to me.

A big thanks to my second big family in Siena, the University Chapel of St. Vigilio. Thank you all for the endless love that is still surrounding me.