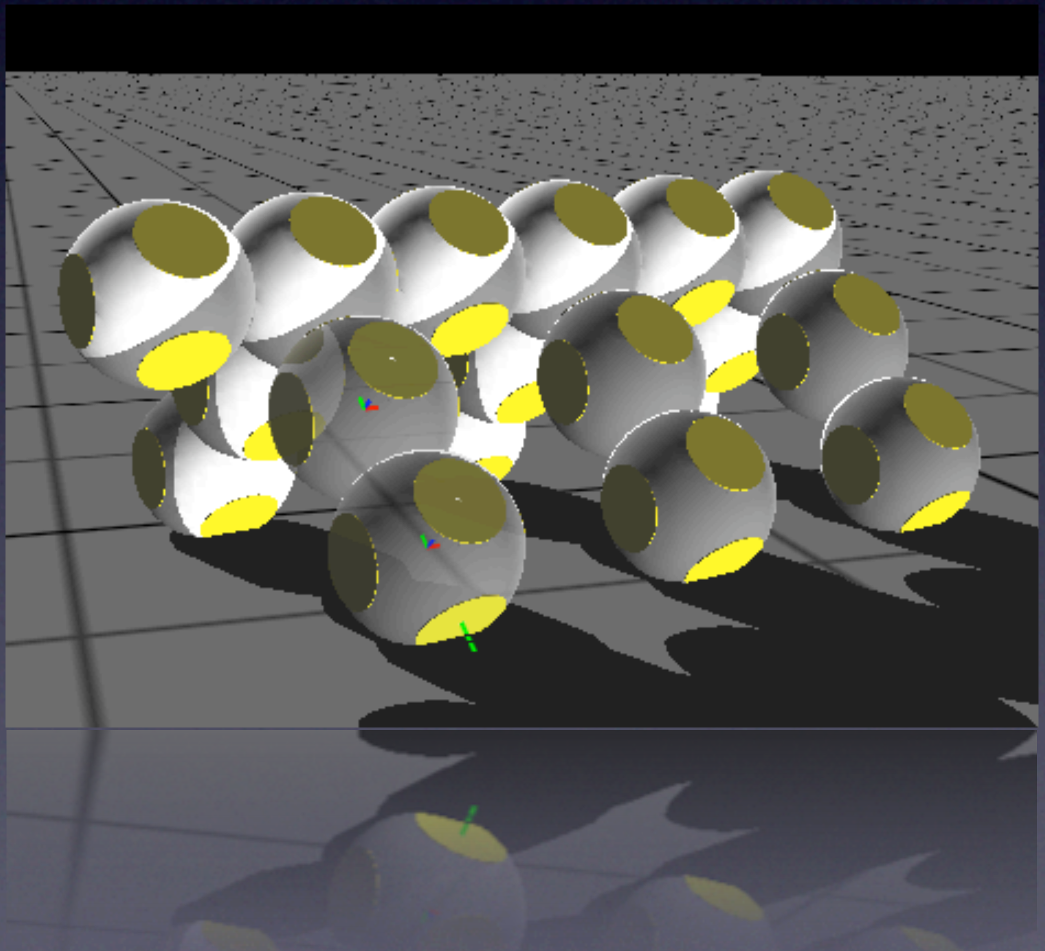
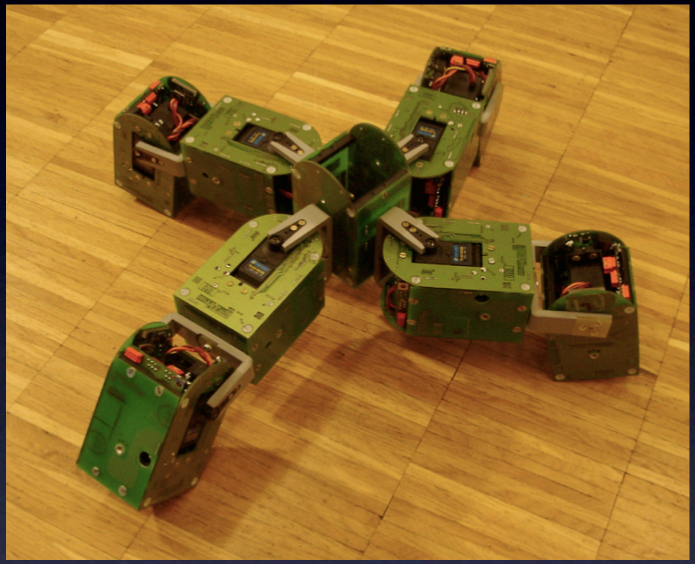
Roombots
CPGs, Symmetries and Online Learning



TULEU Alexandre

Semester Project

How the problem was formerly adressed.



(Jérome Maye)

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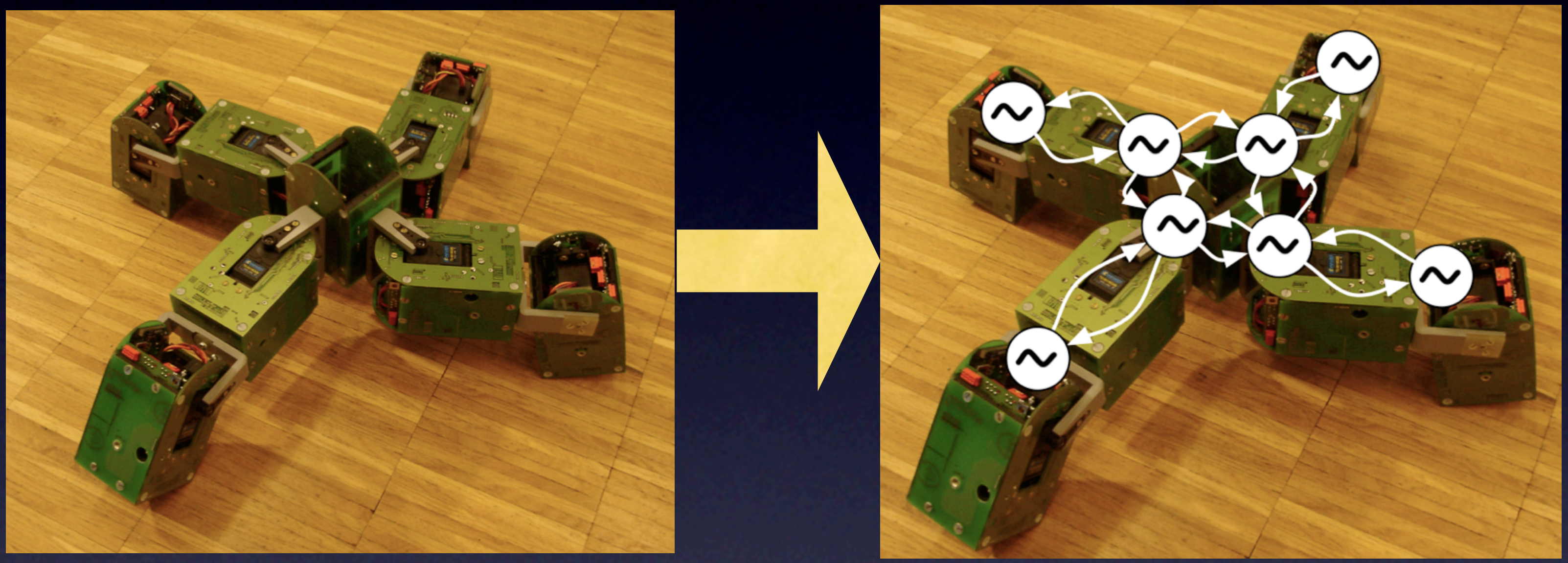

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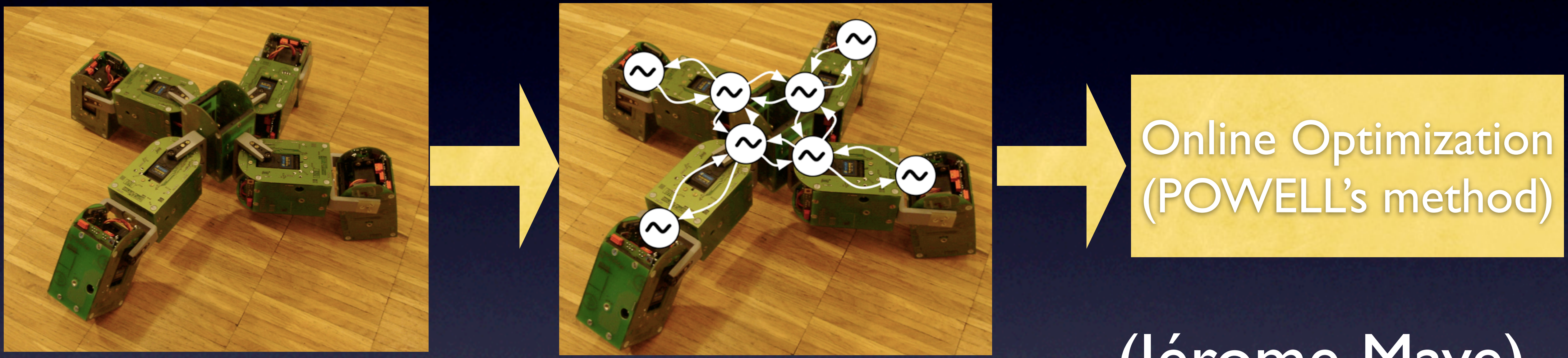

Online Optimization (POWELL's method)

(Jérome Maye)

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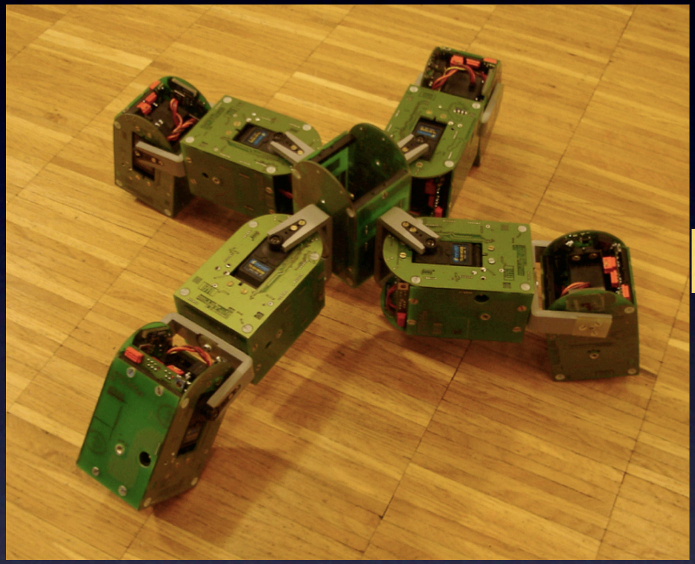

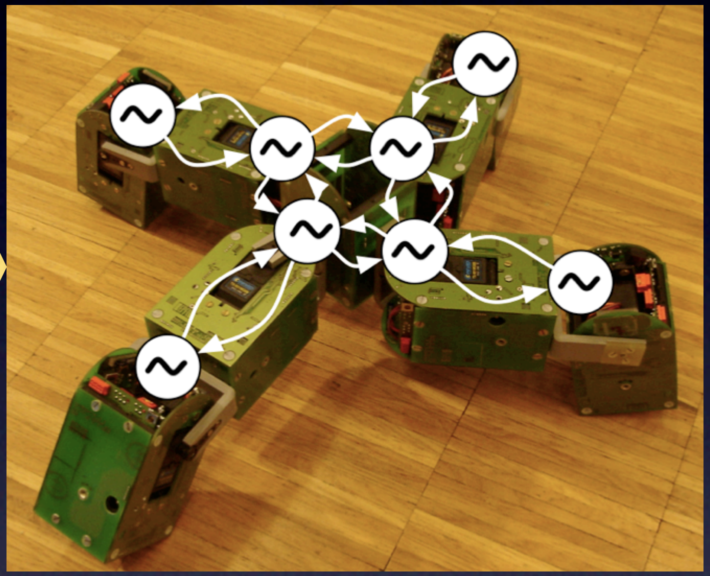

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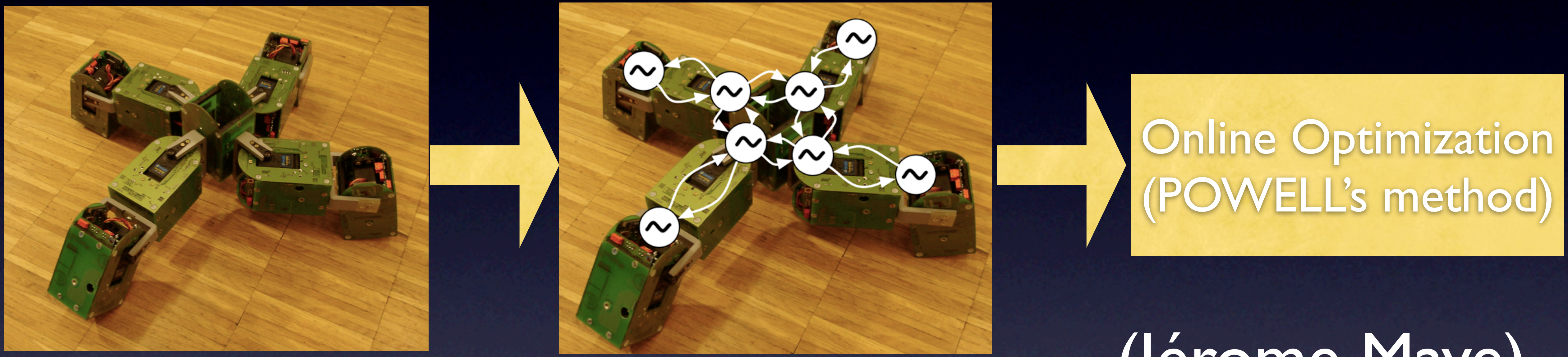

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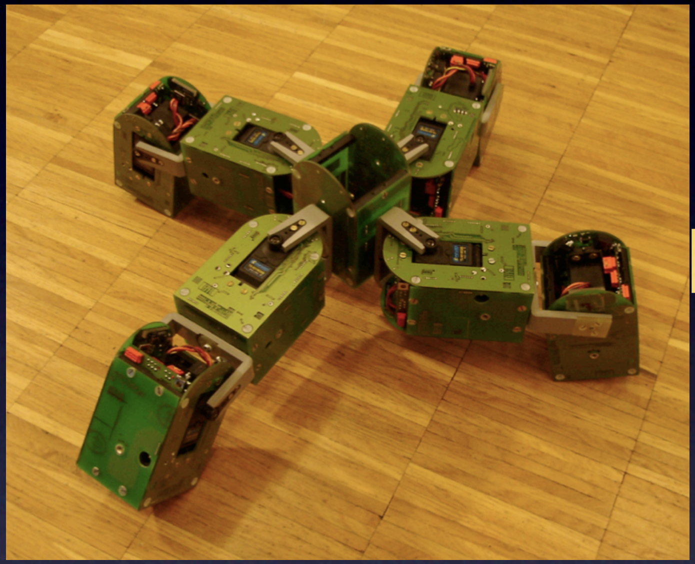

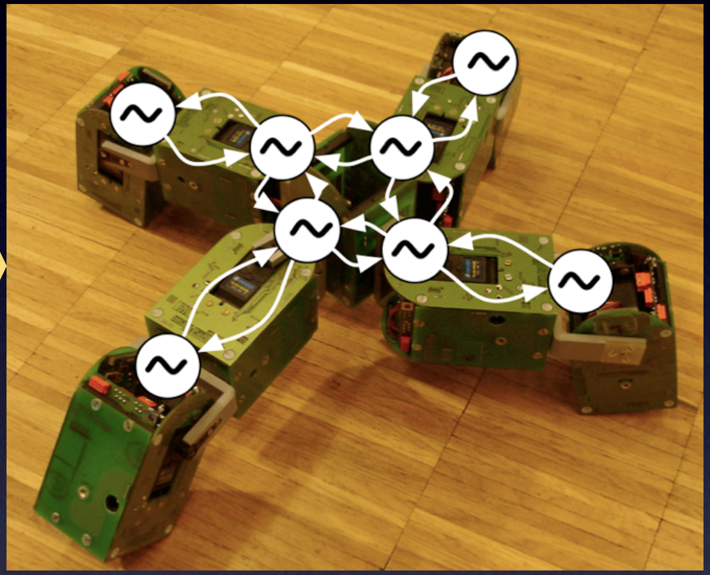

Online Optimization (POWELL's method)

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Problems encountered :

- Manual design of the CPG is not scalable !
- Optimized search for the topology of the network neither !
- Powell's method less suited for Roombots (multi-modal objective function)

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  - Presentation of some software tools created.
  - Study of a special case : the quadruped Roombots
  - Presentation of an automatic processus for designing CPG.

Making tools for Roombots

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  - The modules were previously modelised by two spheres.

Results

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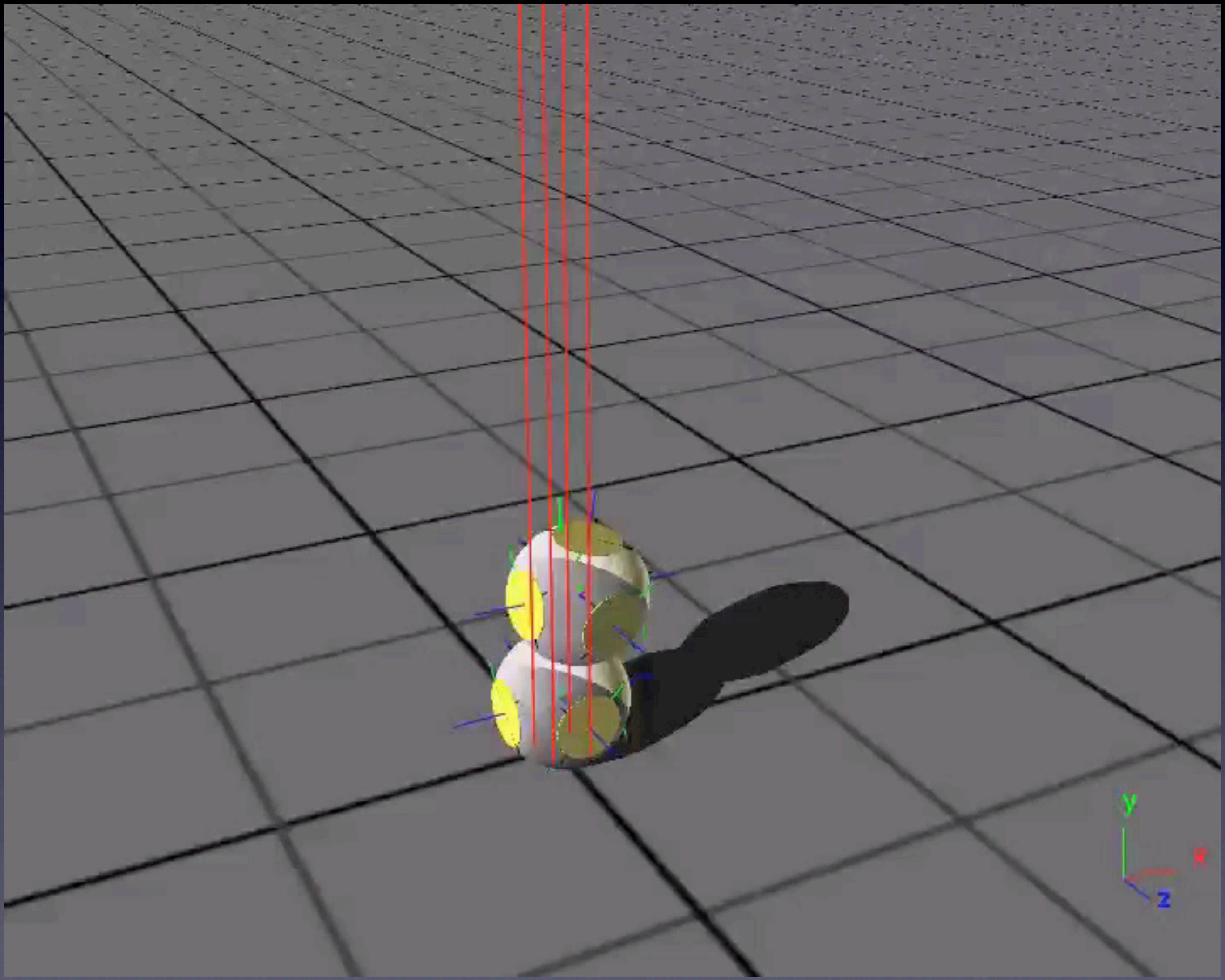

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    - Analyse the choices we made, in order to synthesize them in an automatic process .

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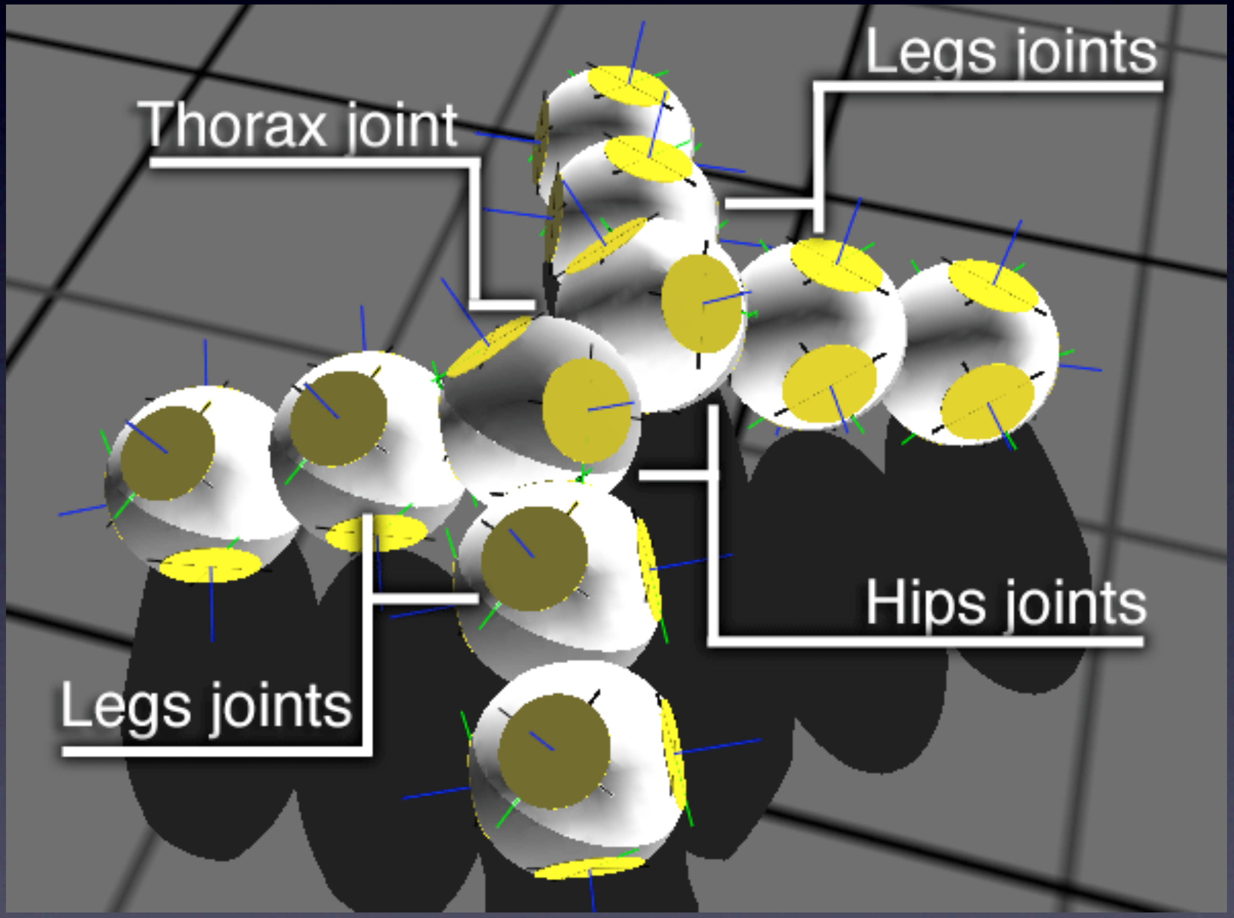
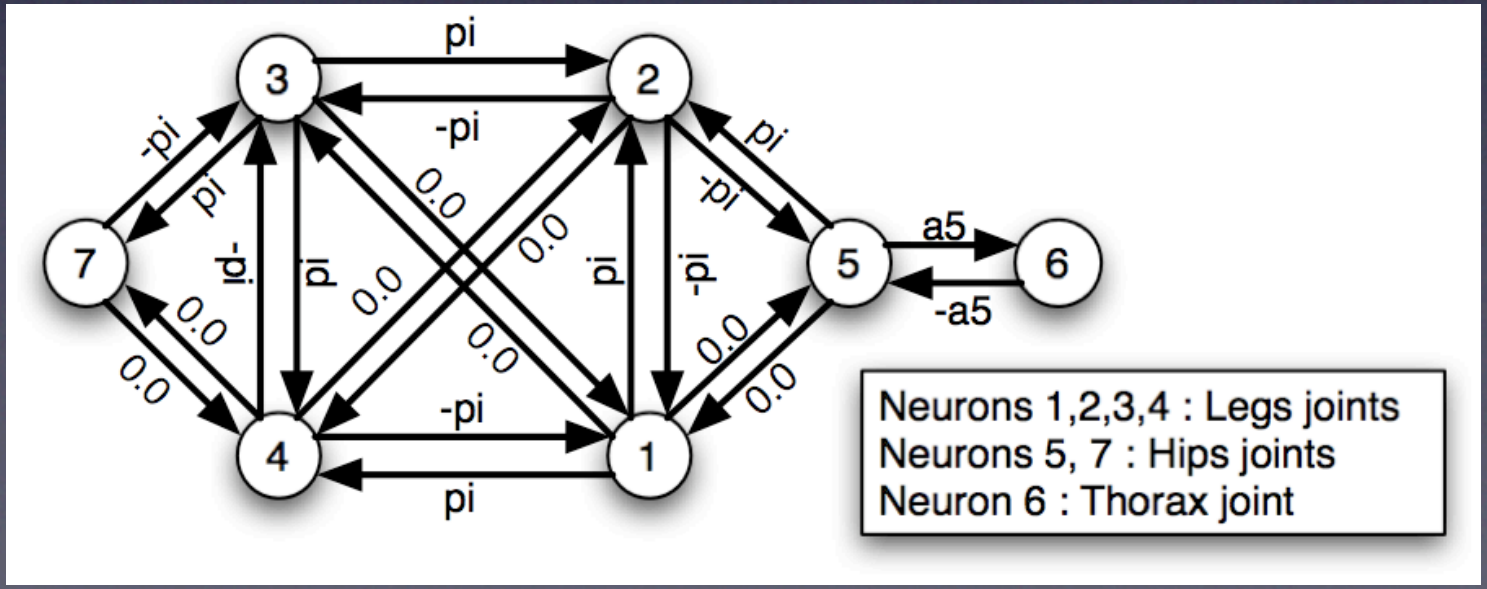
- Symmetries in CPG help to determine the resulting pattern (Ludovic Righetti, Golubitsky).
- Then it helps us to reduce our search space, by adressing the same value to symmetric peers. (Sandra Wieser)

Design of the robot.

- Try to find the most symmetric structure.
- Make the legs to have the same motion.
- Make the structure able to assymetrize itself, in order to select which leg to use (action on the Thorax joint).



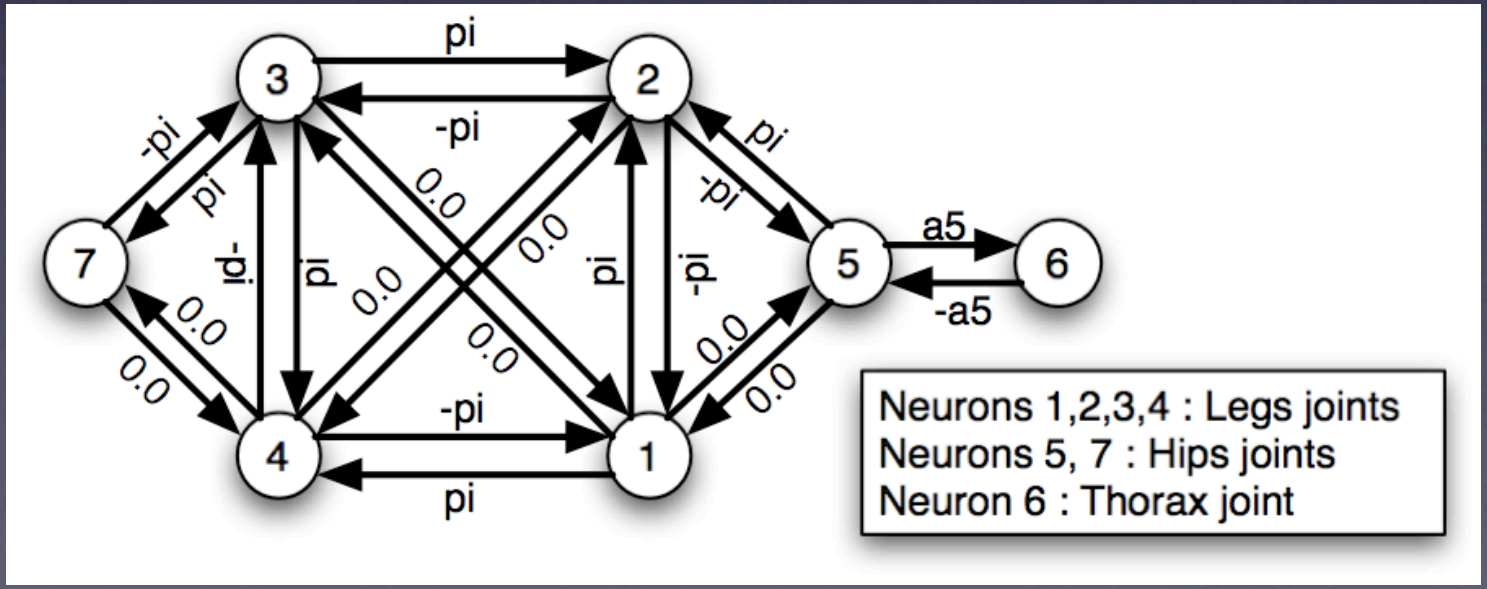
Design of the CPG



Neurons 1,2,3,4 : Legs joints
Neurons 5, 7 : Hips joints
Neuron 6 : Thorax joint

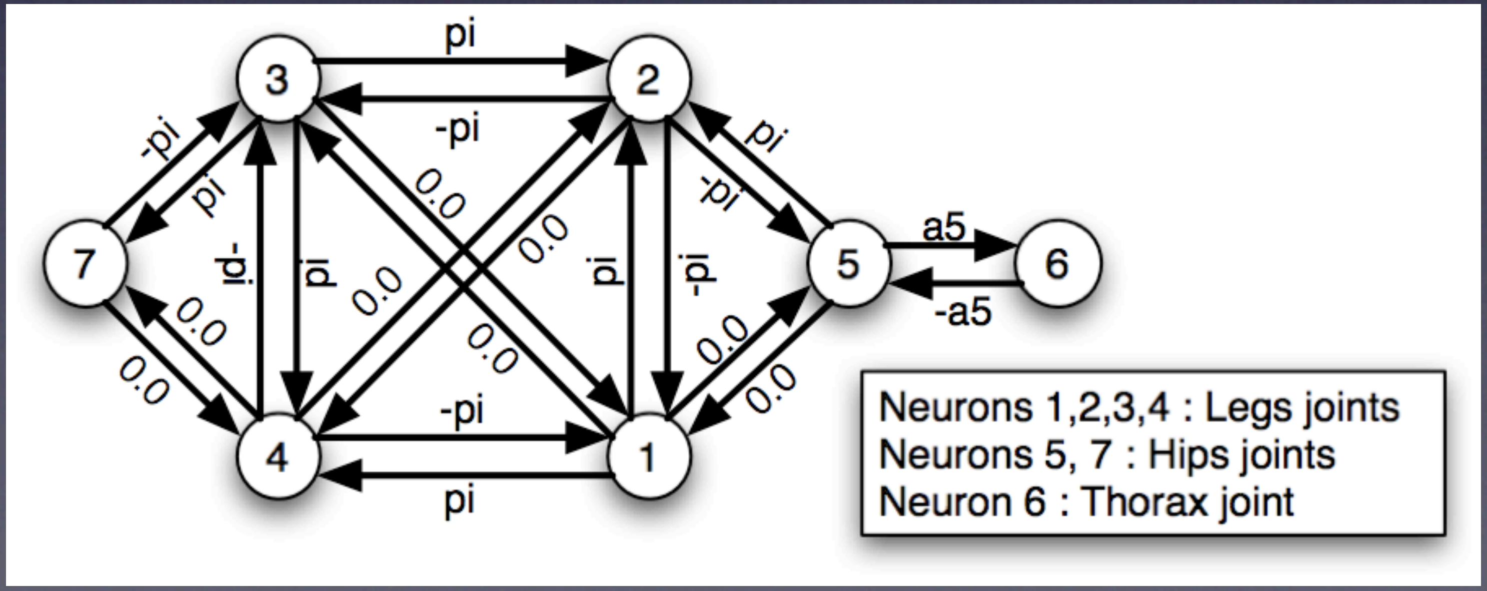
Design of the CPG

- Designed to provide a symmetrical trot.



Design of the CPG

- Designed to provide a symmetrical trot.
- Graft the central part of the neuron to synchronize with the leg part.



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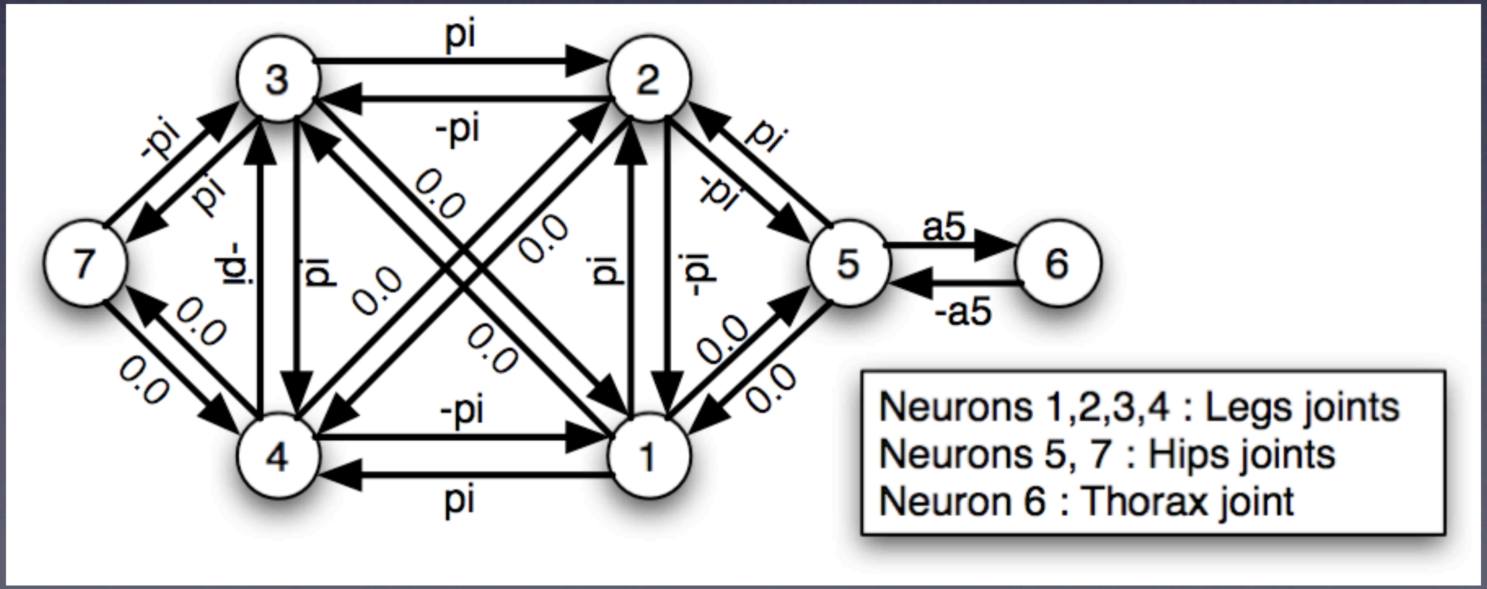

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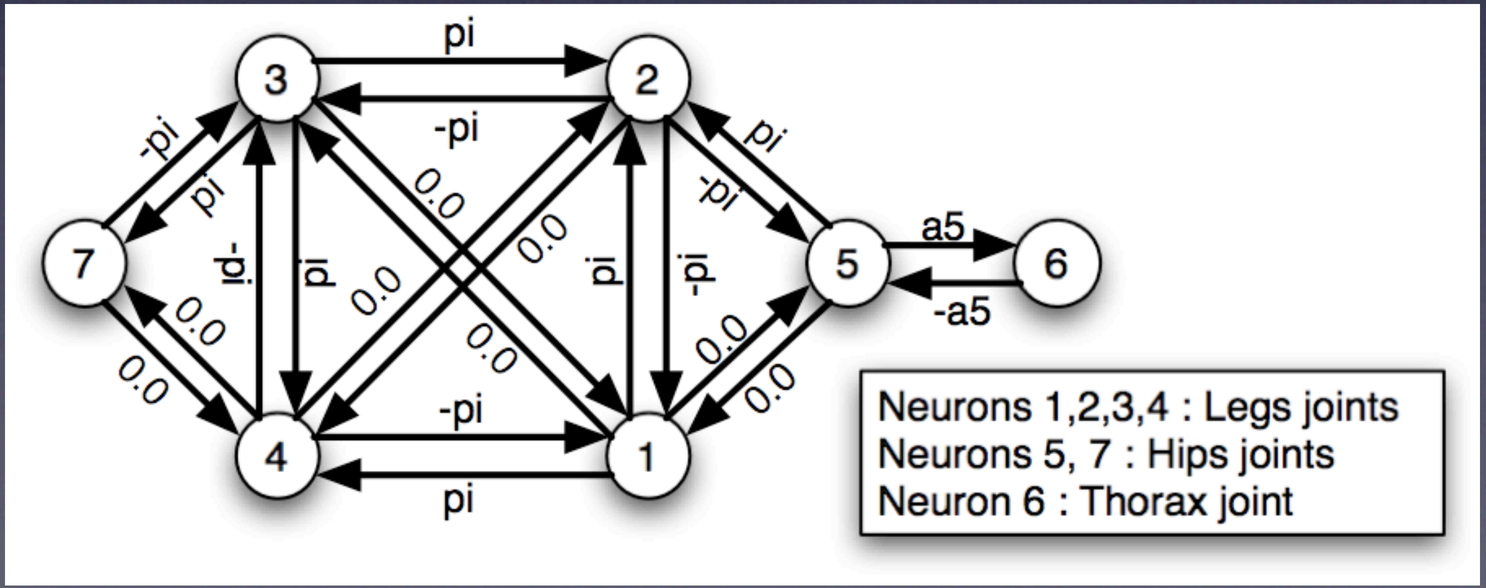
- The leg parts of the structure have a fixed synchronization, but a free offset.



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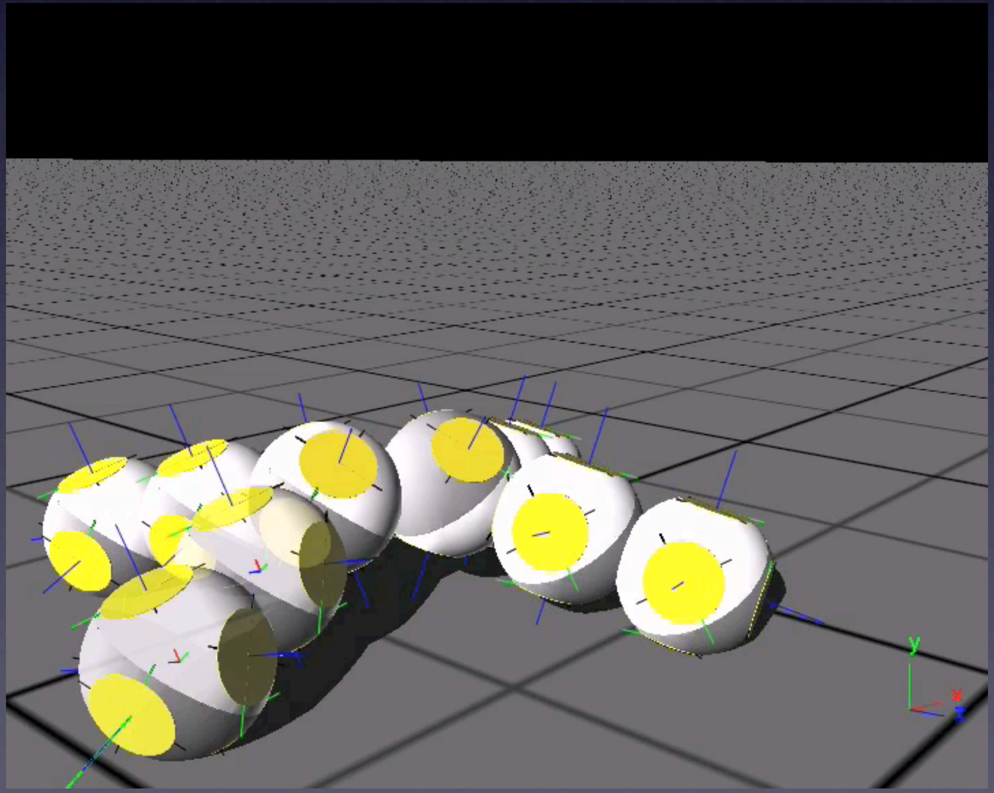
Results obtained.

With fixed frequency

With optimized frequency



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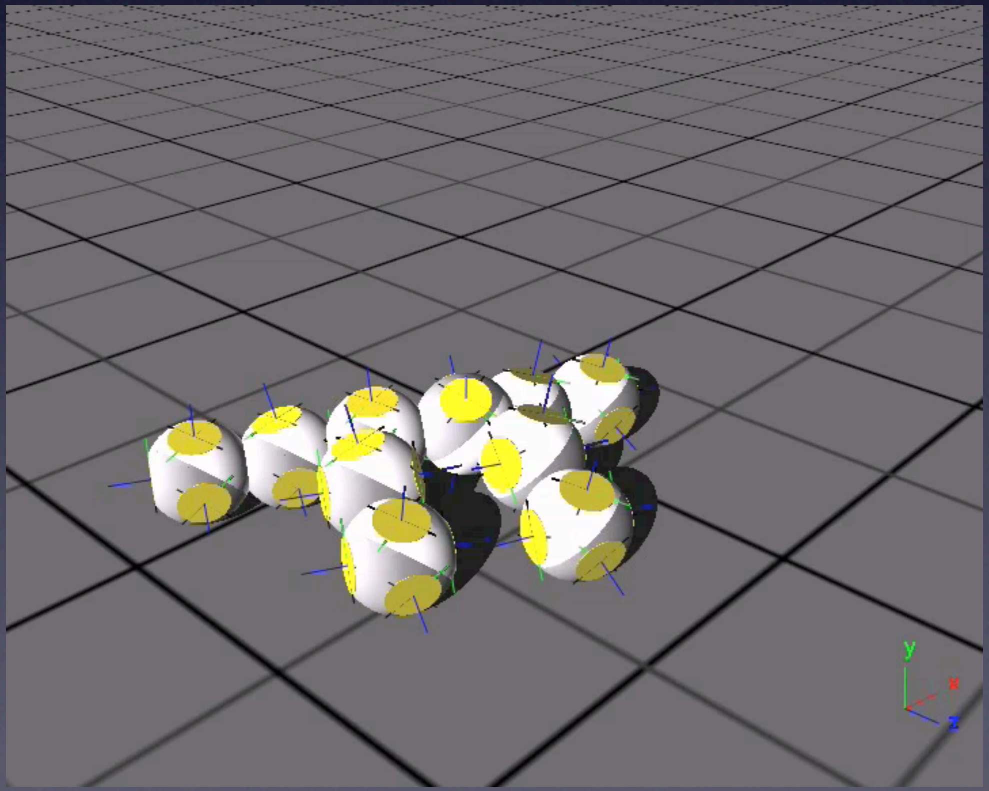

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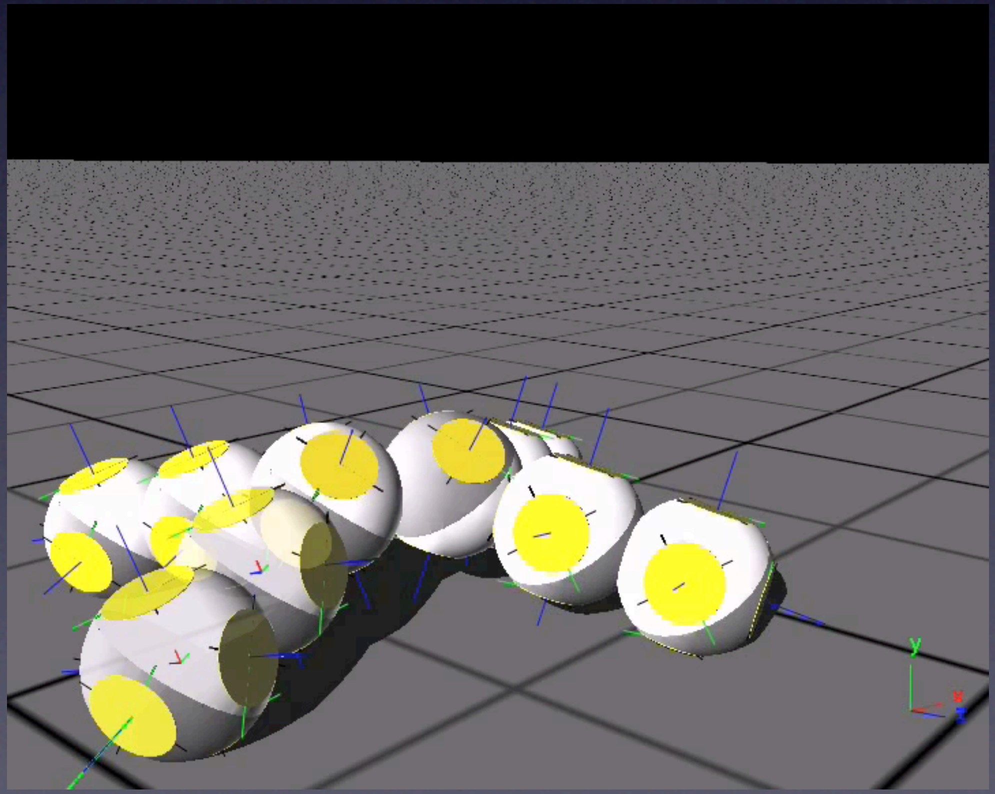
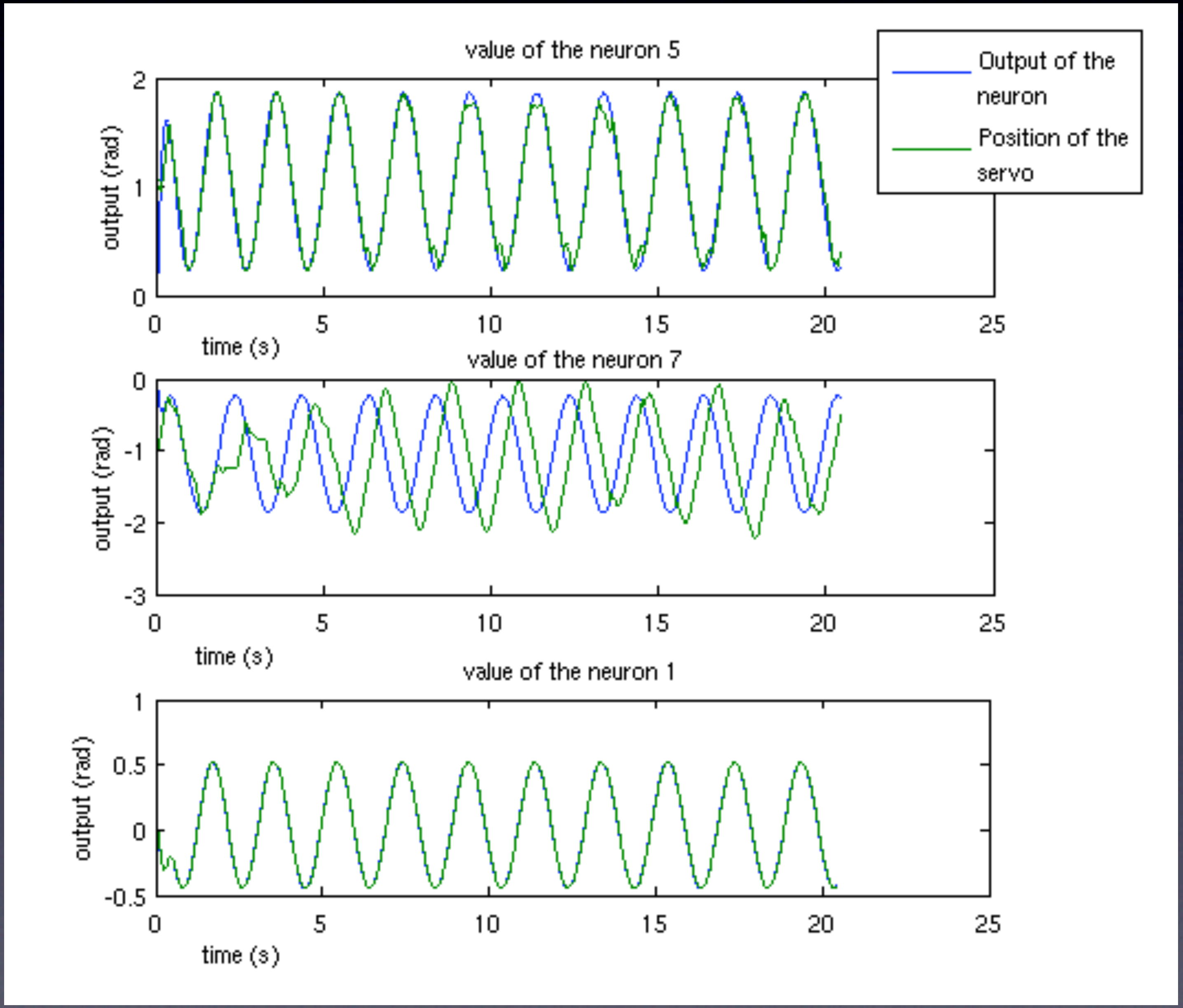


Problems : Servos limitation

- Have a limited (slow) speed : 25 tr.min^{-1}
- Should add some constraints on the search space.
- Should add some "control feedback" in the CPG.



Towards an automatic designer for CPG

Choices we made for the quadruped :

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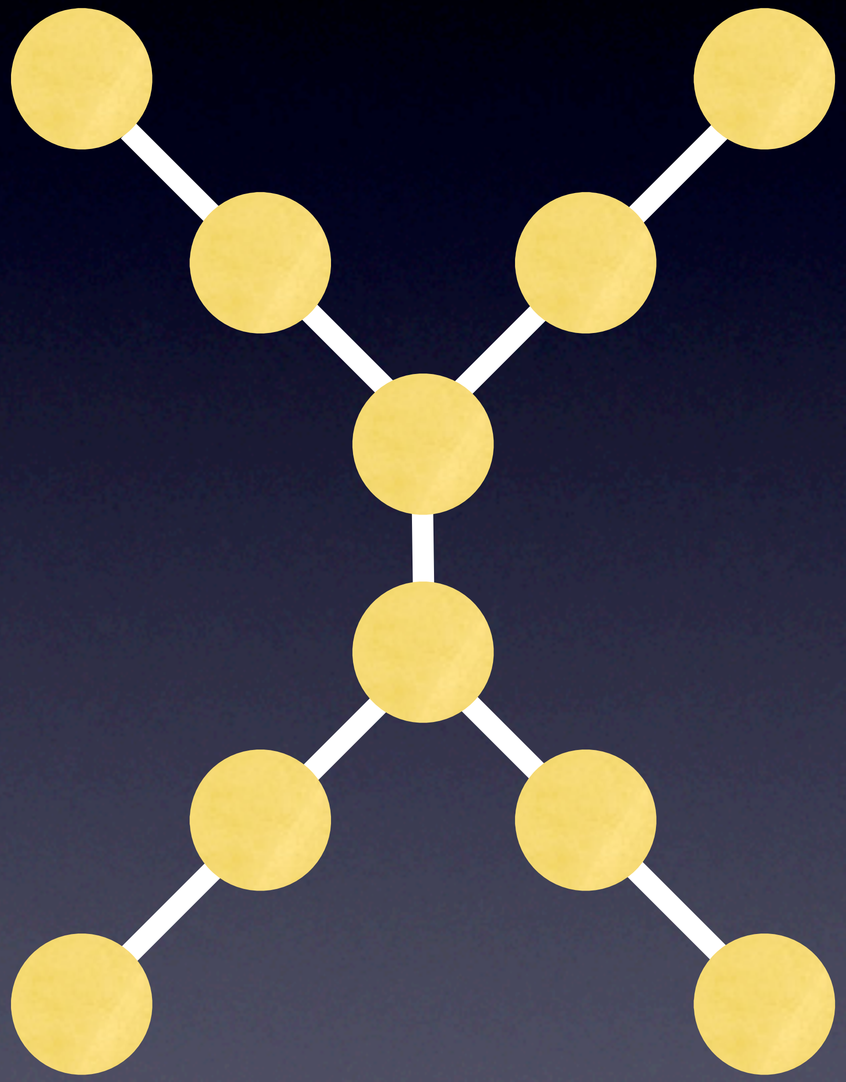
Steps of our algorithm :

- Classify the “leg” and “body” parts.
- Find the symmetries in the structure
- Set up the CPG, according to the symmetries, classification and heuristic rules.

Module Classification

- We forbid Cycles. The Graph is a tree.
- We classify all the leaves as “legs” part.
- “Legs” property is propaged to parent, if it has only one child.



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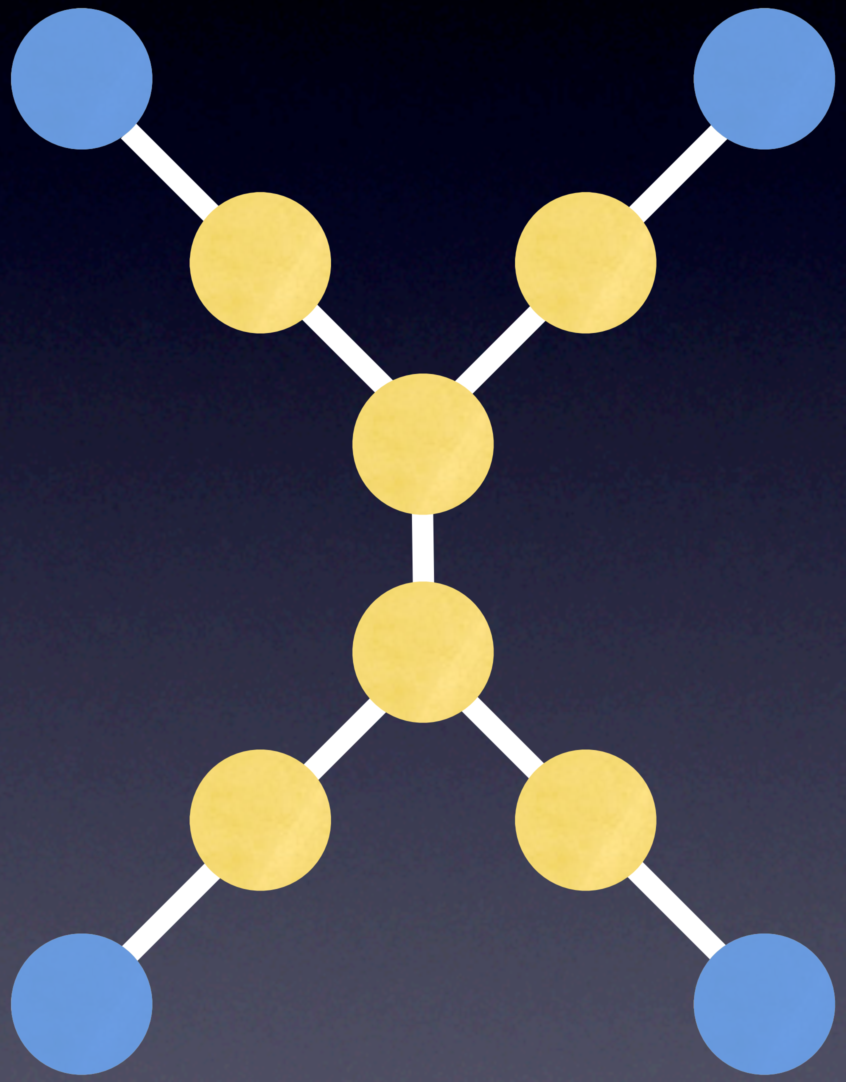

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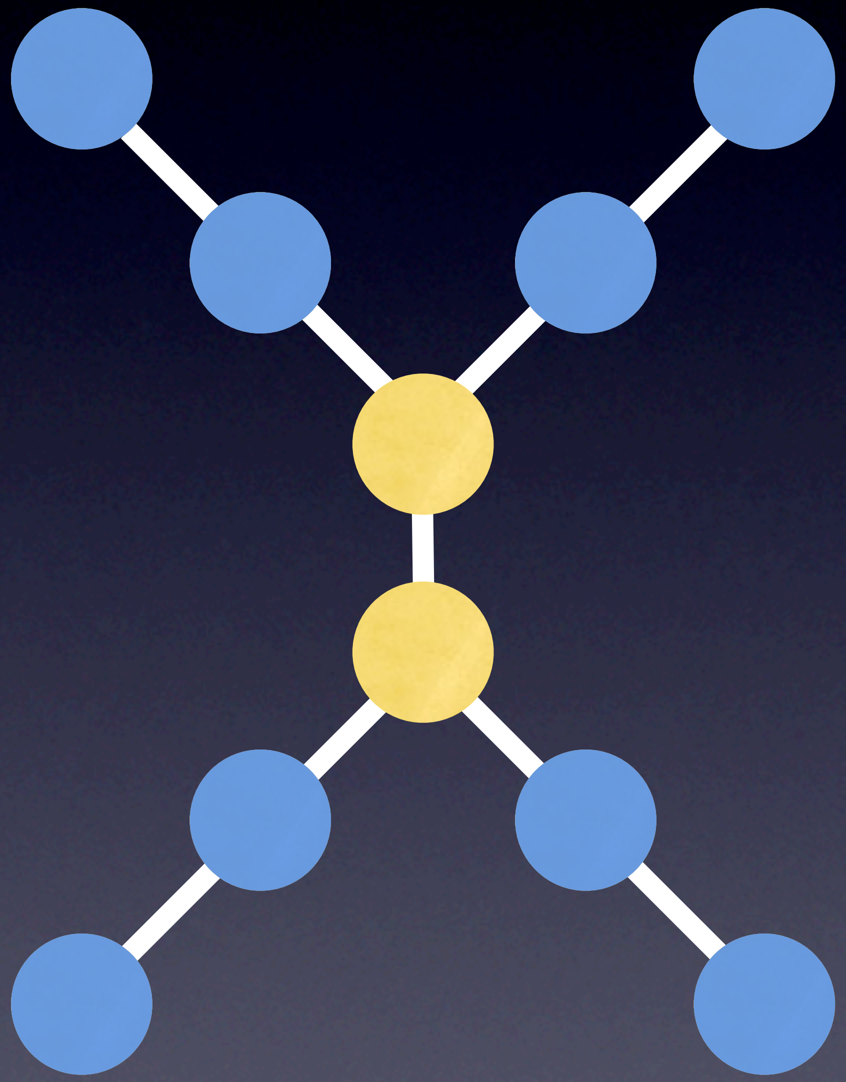
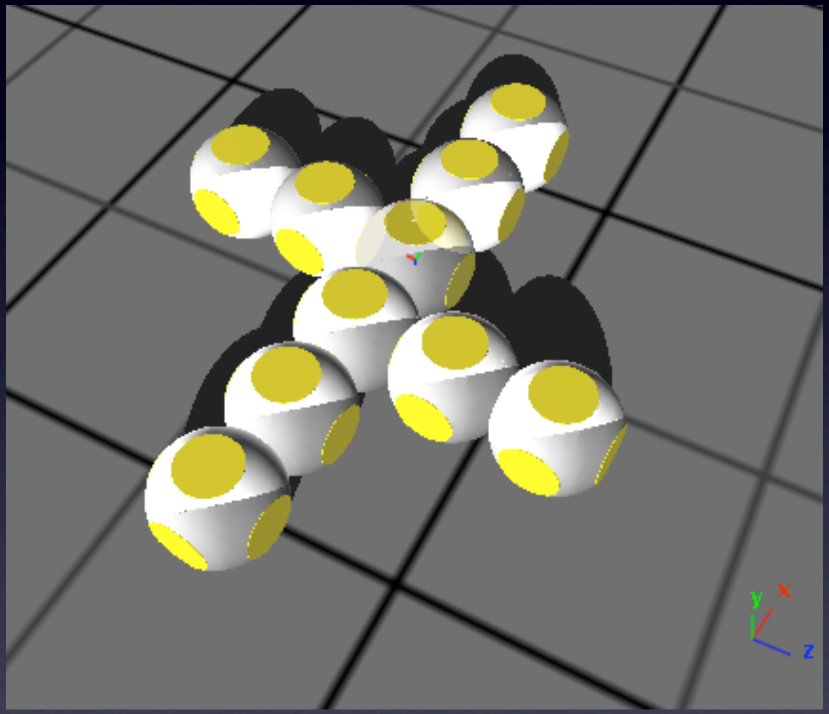
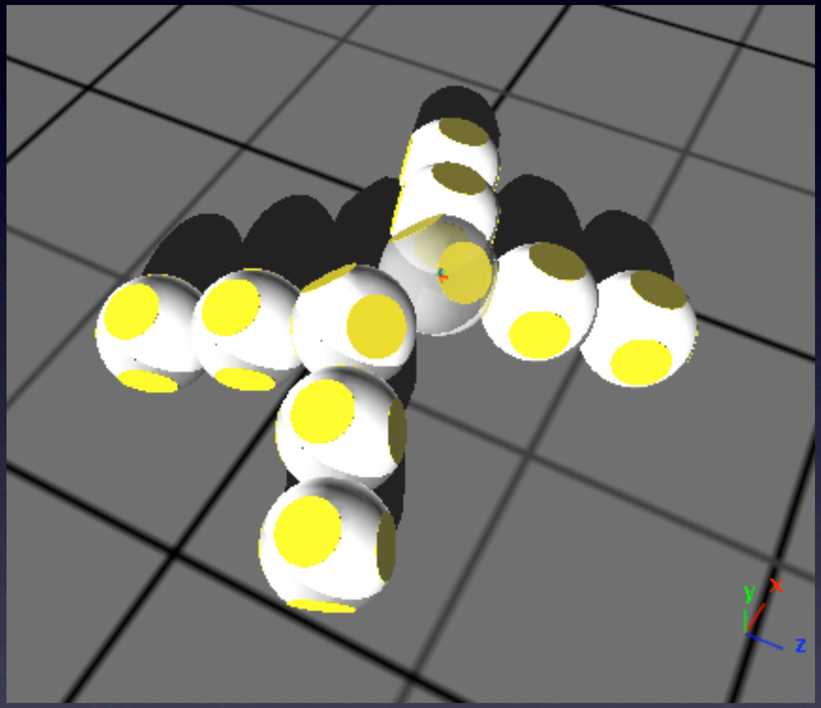


Find the symmetries

Hierarchical vs Morphological





Hierarchical symmetries is a prerequisite for Morphological ones.

Morphological symmetries can be found as the result of an **Optimization Process** on the servo position.

Estimating how much Morphologically symmetric a structure is.

- For a given position of the servo, we have to check for all the hierarchical symmetries, how much they are close to a spatial symmetry between modules.
- As a result of Graph Theory, this problem can be reduced to test symmetries among several pairs of modules.
- Thanks to the Roombots kinematics model provided by (Mikaël Mayer), the expression of how much two modules are symmetric can be adressed.

Therefore, we can provide an **objective function** for our optimization algorithm.

Estimating how much two modules are symmetric.

- Thanks to the given servo position and the kinematics models, we can compute the Rotational Matrix R from one module to another .
- The two modules are symmetric when : R^2=Id. (axial symmetry)
- “How much they are symmetric” is then the “distance” from R^2 to Id.
- Open questions : Which space to compute the distance in; reflexive symmetries ?

Questions ?