Locomotion in modular robots using the Roombots Modules

Semester Project

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Goal of the Project

- To explore the locomotion possibilities of a modular robot.
  - This robot is composed by passive elements and Roombots robots
  - The used CPG is the one developed by Ludovic Righetti at BIRG

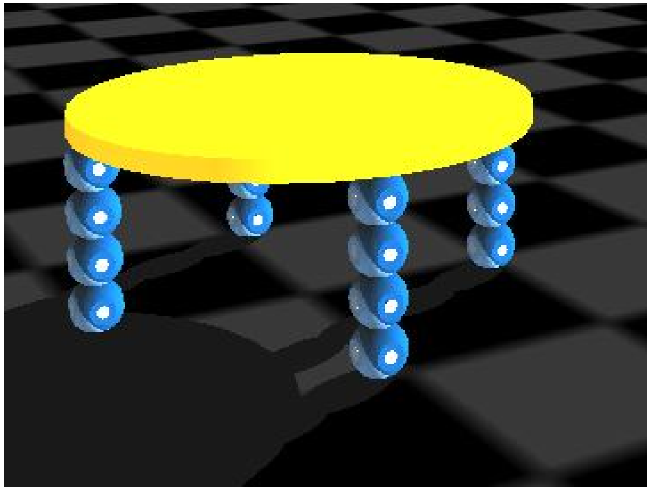
(*Pattern generators with sensory feedback for the control of quadruped locomotion,* Ludovic Righetti and Auke Jan Ijspeert)

  - The optimization method used is Powell's algorithm

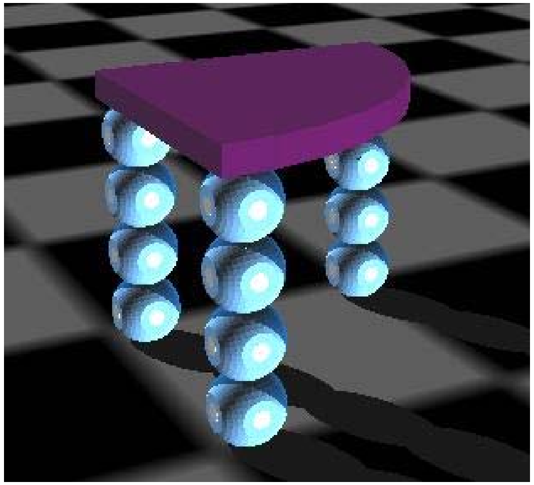
- To discuss the pertinence of the initial decisions

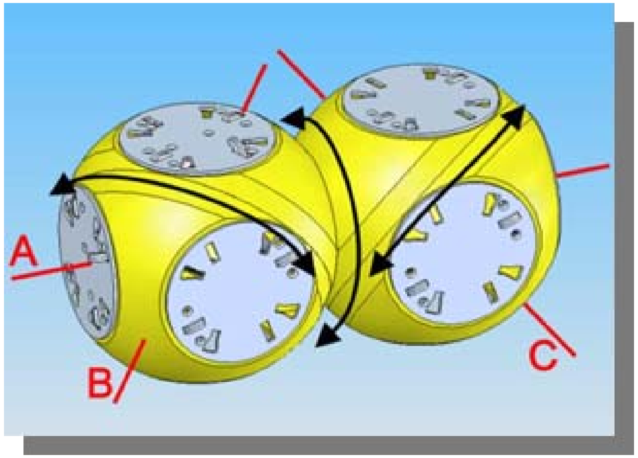
Robot's Structure

- Table
  - 4 legs, 2 modules per leg



- Chair (stool)
  - 3 legs, 2 modules per leg

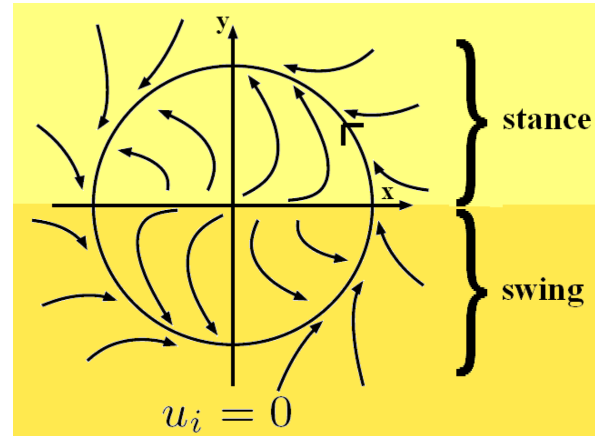




Roombot

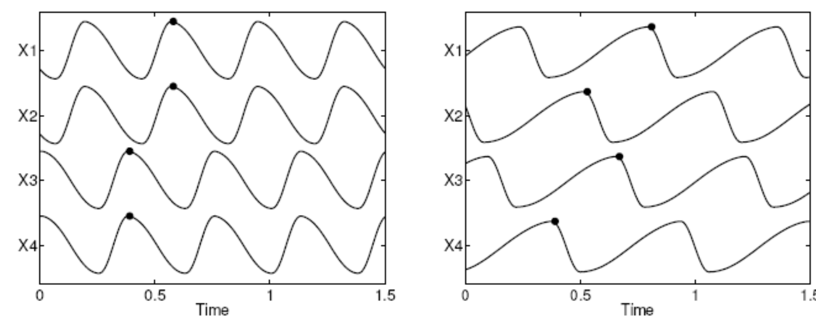
CPG (Central Pattern Generator)

- Principle
  - Distinction between swing and stand phase
  - Limit cycle behavior
  - Possibility of using sensor feedback and coupling
  - Possibility for the actuator to be in continuous rotation



- Example of gait generation:

  (*Pattern generators with sensory feedback for the control of quadruped locomotion,* Ludovic Righetti and Auke Jan Ijspeert)



$$\begin{bmatrix} 0 & 1 & -1 & -1 \\ 1 & 0 & -1 & -1 \\ -1 & -1 & 0 & 1 \\ -1 & -1 & 1 & 0 \end{bmatrix}$$

Bound

$$\begin{bmatrix} 0 & -1 & 1 & -1 \\ -1 & 0 & -1 & 1 \\ -1 & 1 & 0 & -1 \\ 1 & -1 & -1 & 0 \end{bmatrix}$$

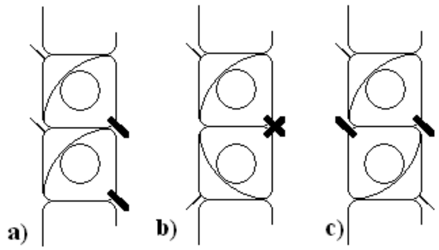
Walk

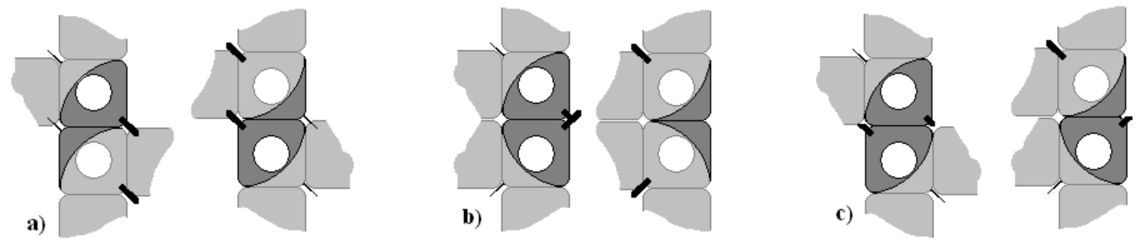
Free Parameters

- Continuous / Discrete Parameters
  - Continuous parameter can be optimized with Powell's method
    - Example: amplitude of oscillation $\in [0,3.14]$
  - Discrete parameters have to be arbitrary set, or tried by hand.
    - Example: A servomotor can work as oscillator or wheel. So the "working mode" parameter is OSCILLATION or ROTATION.
  - The number of parameters to optimize has to be as small as possible, or the optimization process will take too much time.

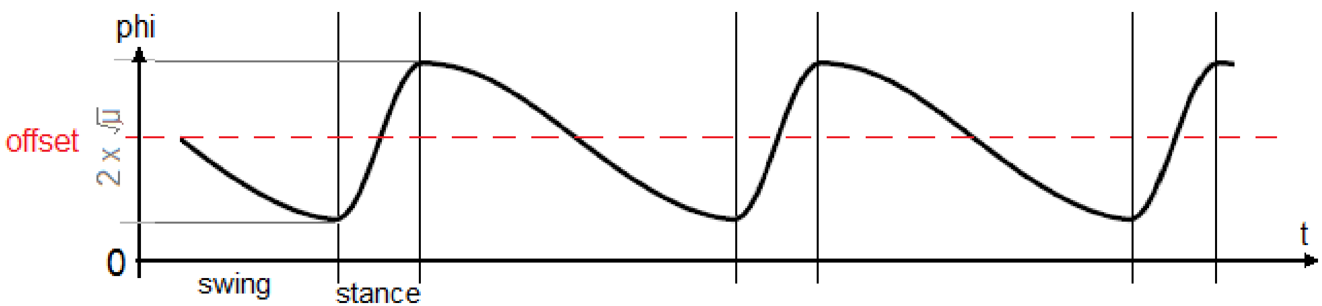
Free Parameters

- Connections between modules





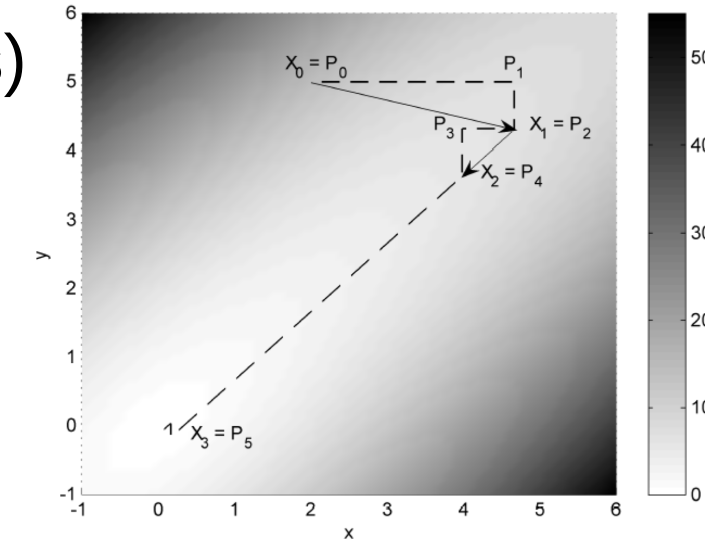
- CPG and servomotor phi=±offset +X



- A total of 124 continuous parameters and 26 discrete parameters. Continuous parameters are reduced to 7.

Optimization

- Powell algorithm (N dimensions)
  - Direction set algorithm
  - Gradient descendant



- Golden Search (1 dimension)
  - Also gradient descendant
  - Minimum between brackets, brackets closer at each iteration.
- Fitness function:
  - To maximize: radial distance covered in 20 seconds
  - To minimize: $\frac{1}{1+D}$, where D is the distance (P_{final}-P_0)

First Results (1)

- We tried an optimization of the parameters for the chair (3 legs, 2 modules per leg).
- The modules have 3 motors: s1, m1, s2.
- There's a common value for all s1 motors, another for all s2 motors, and so on
- Each configuration of rotation and oscillation was tested. (3 motors, 2 possible configuration per motor, 2^3 optimizations)
- An optimization process takes around 2 hours

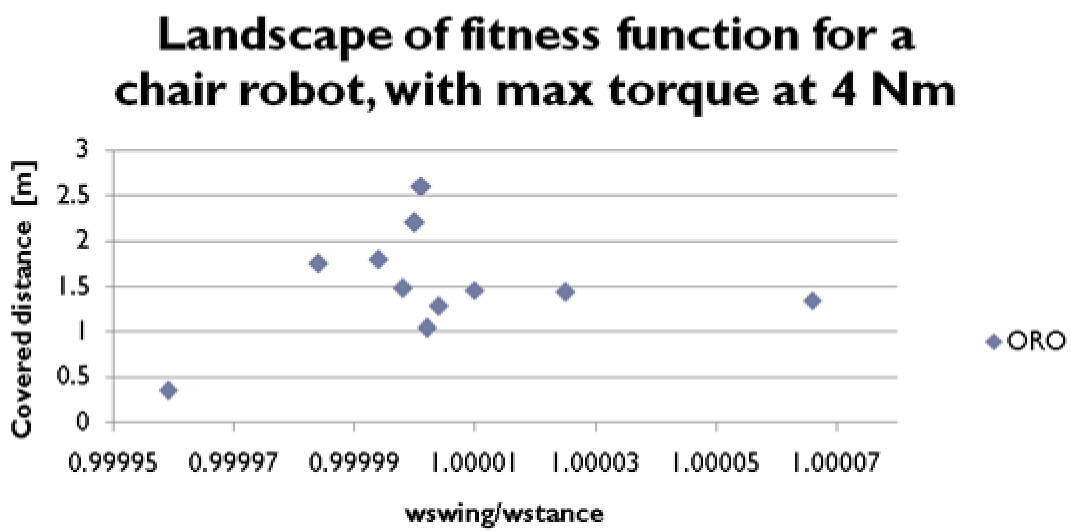
First Results (2)

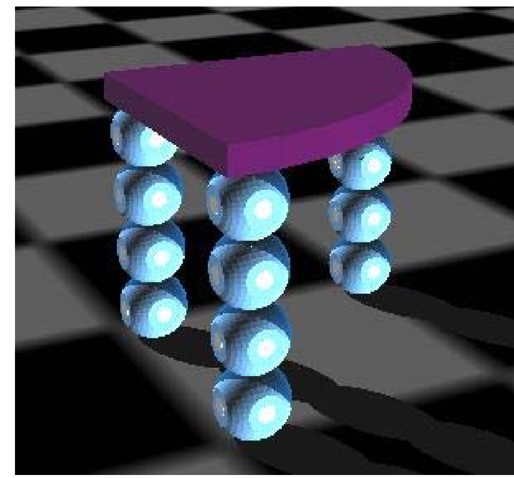
	Distance Covered [m] (P_0=A)	Distance Covered [m] (P_0=B)
RRR	-	4.32
ORO	3.80	12.66
RRO	2.87	1.98
ROR	0.90	7.68
ROO	1.75	-
ORR	5.14	6.74
OOR	6.11	2.36
OOO	4.30	4.61

- The fitness function has various local minima/maxima
- Powell's can't find the global minimum/maximum of the function
- Run Powell many times with different random starting points, then taking the maximum of the maxima

First Discussion (2)

- Optimization
  - Fitness landscape for critical solutions



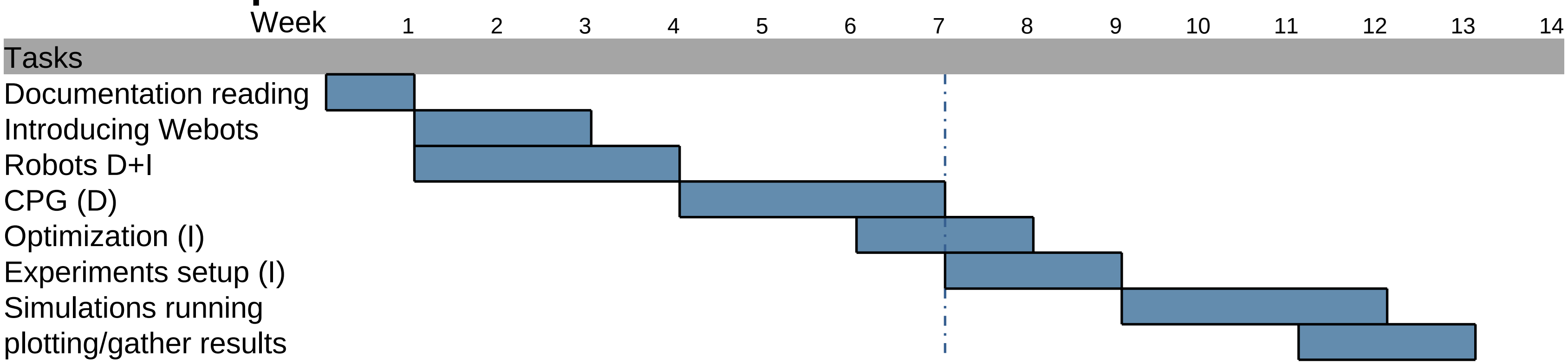


Two factors make the function to optimize irregular (noisy):

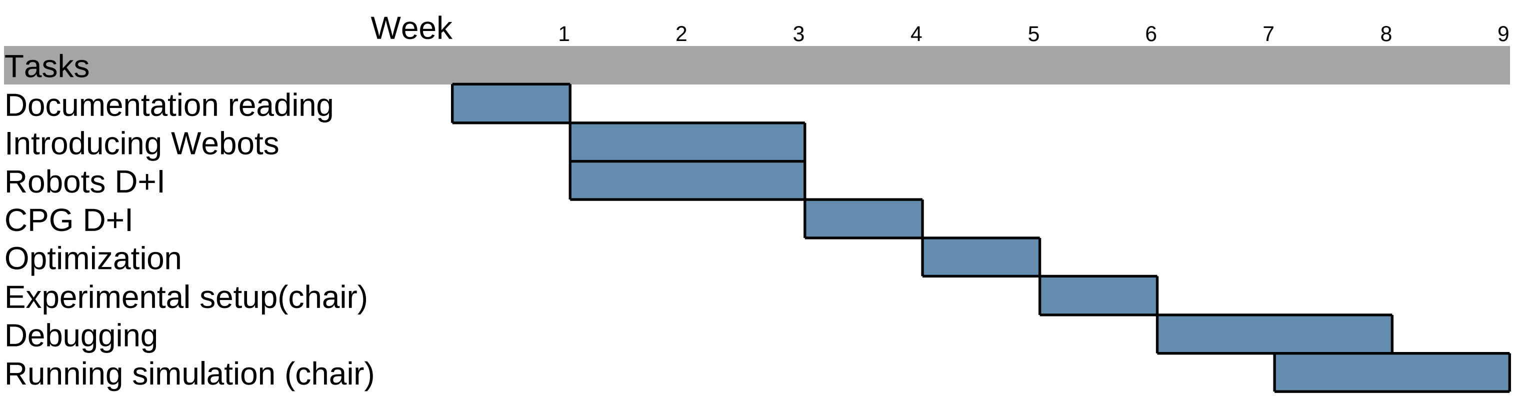
- Constraints due to passive elements (legs torn and stuck)
- Maximum torque values makes sometimes the robot fall

Schedule

- Initial plan

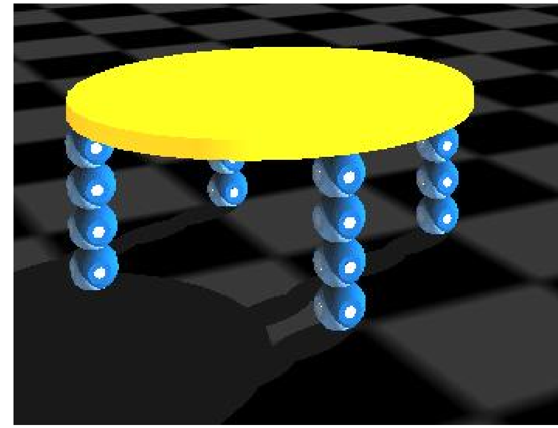


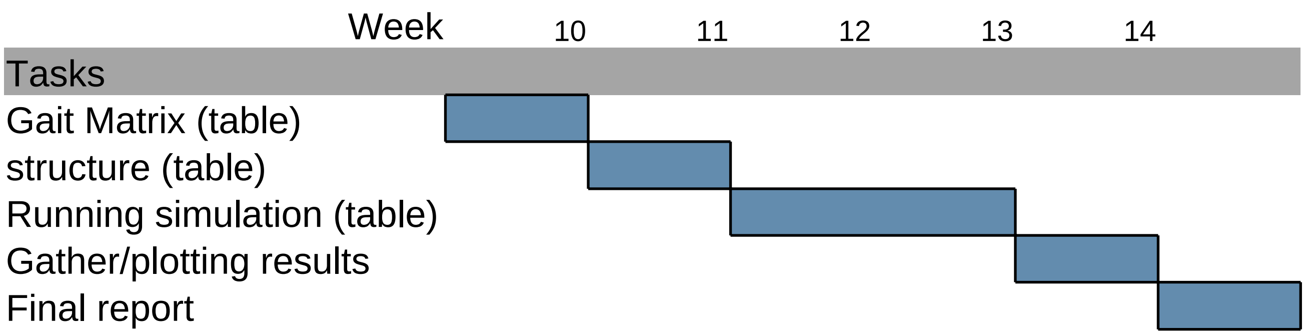
- Actually done



Schedule

- Still to be done
  - Exploration of motion's possibilities of the table robot
  - Implementation of different gaits matrix
  - Test of different robot/parameters configuration





Results(3)

- Bad results are not only due to torque values…