Humanoid Robot Control Recruiting Muscles, Reflexes and a Central Pattern Generator

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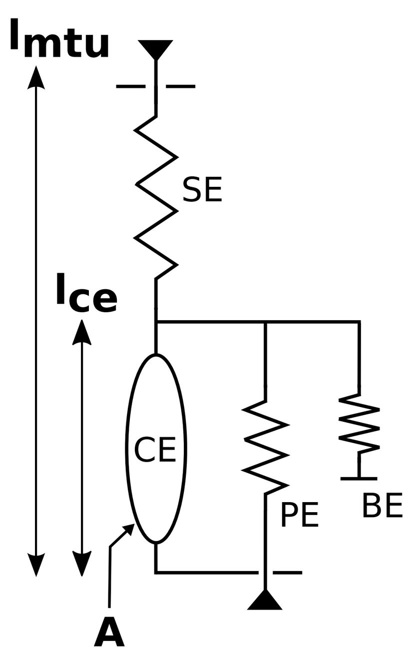
Motivation & Implemented algorithms

While classical approaches achieve nice gaits with humanoid robots, we are still far from the **impressive human walking capabilities**.

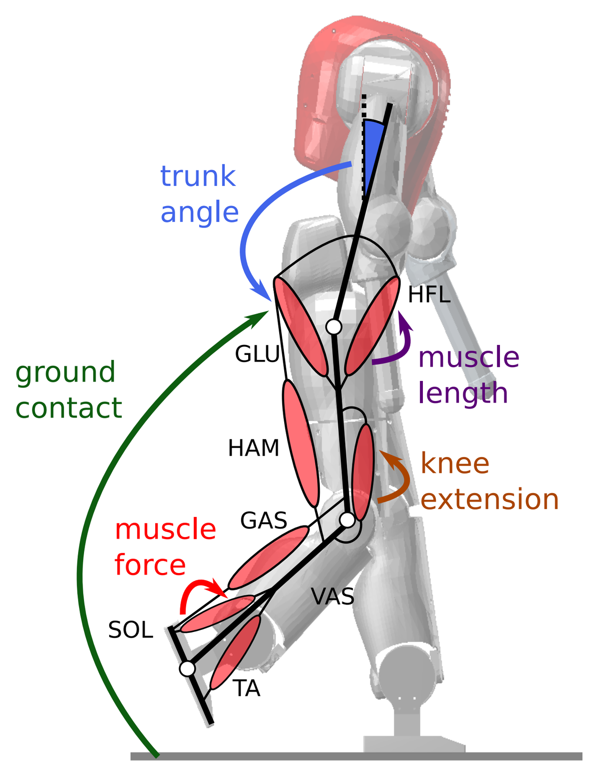
Bio-inspired algorithms are being developed, generating more **energy-efficient** and **human-like** gaits, but they are mostly limited to simulation studies (Geyer and Herr, 2010).

We develop controllers based on **virtual muscles controlled by neuronal stimulations** like reflexes an a central pattern generator.

This is tested on the a **full-body humanoid robot**: the COMAN. It also allows to improve our **understanding of human locomotion**.



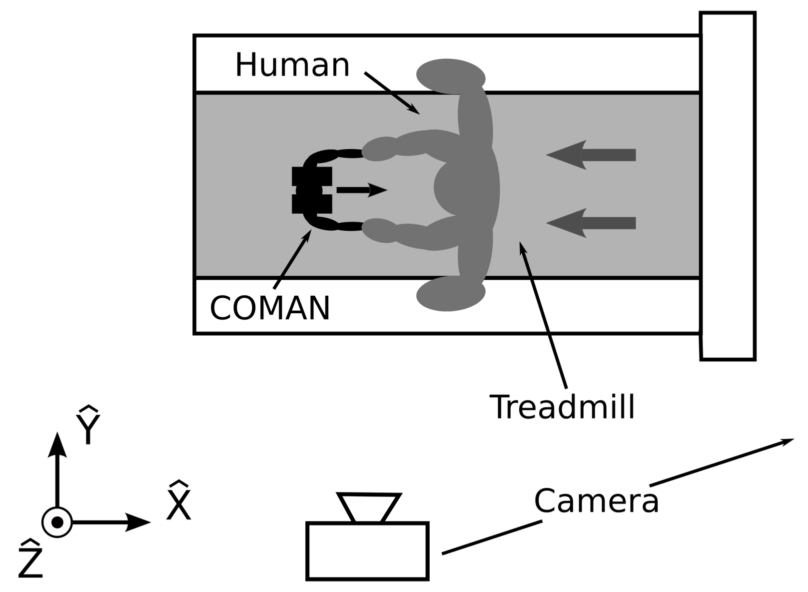
Hill muscle model

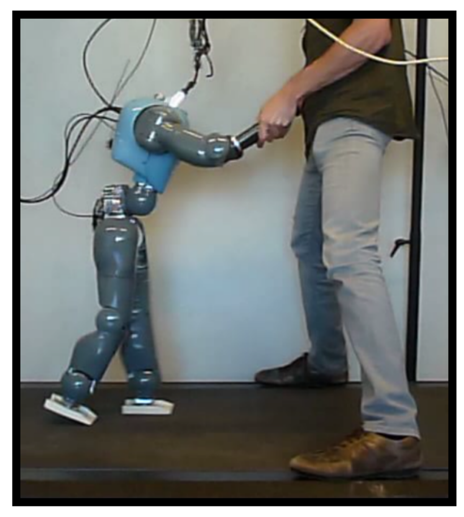


Leg muscles

Experimental setup

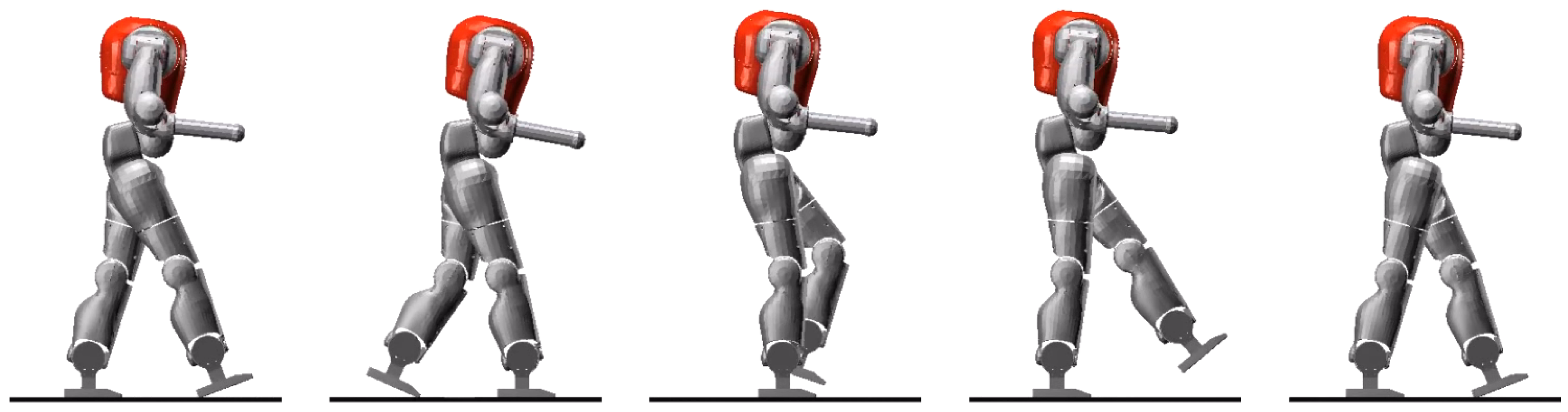
Due to the lack of lateral balance control, an **extra upper body controller** is developed to let a human operator provide lateral stability, without affecting the sagittal plane.





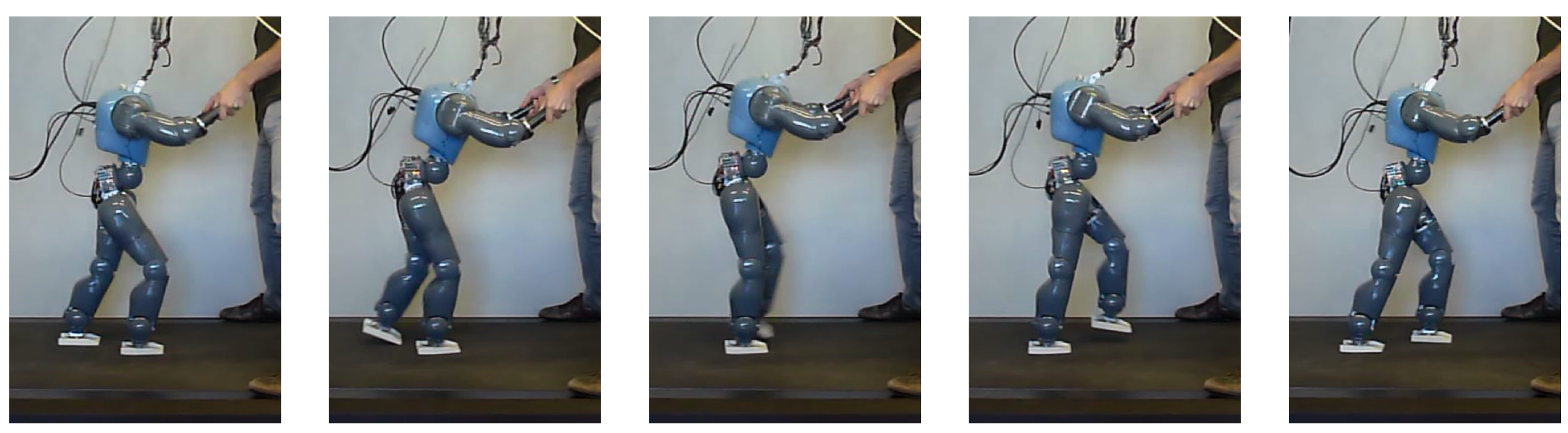
Reflex-based controller - from simulation to real hardware

The gait controller is optimized in a **simulation environment**. The objective function rewards solutions **minimizing the metabolic energy consumption**.



t = 0 s | t = 0.2 s | t = 0.4 s | t = 0.57 s | t = 0.73 s

The gait controller optimized in simulation is ported to the **real robot** with no modification.



t = 0 s | t = 0.37 s | t = 0.57 s | t = 0.8 s | t = 1.03 s

Similarities with simulation

- stretched stance leg
- rolling foot at swing initiation

Differences with simulation

- flexed knee during late swing
- shorter steps
- lower step frequency

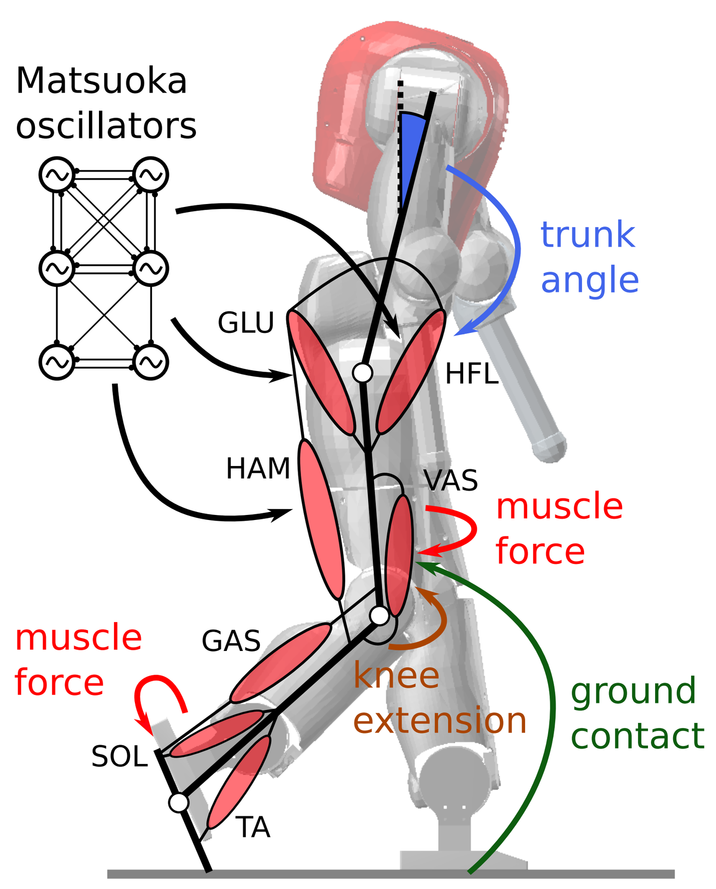
The behaviour of the **stance leg** and of the swing one at **swing initiation** are quite similar in simulation and on the real robot. In particular, the **stance leg** is **fully stretched**, a feature usually absent in most robotic gaits.

The **non-stretched swing leg** issue is due to the **high friction effects** in the robot joints. This impacts both the step length and frequency, reducing the robot speed.

Despite this huge difference in the walking gait, the robot still manages to walk, demonstrating some kind of **robustness** related to this bio-inspired controller.

Speed and step modulation through CPG

A **Central Pattern Generator** (CPG) is a neural circuit capable of producing rhythmic outputs while receiving a simple non-rhythmic input signal.



Leg muscles controlled by reflexes and a CPG

Combining reflexes with a CPG

- Proximal muscles mainly driven by a central pattern generator
- Distal muscles mainly driven by reflex rules

Getting different gaits

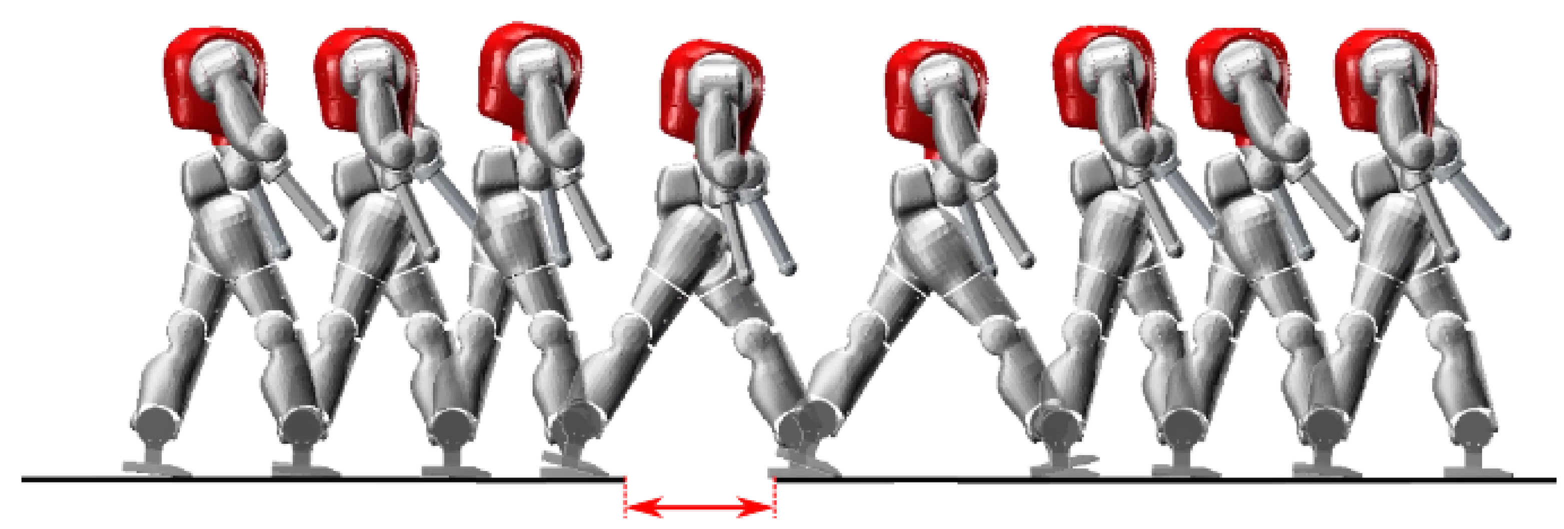
- Speeds ranging from 0.4 m/s to 0.9 m/s
- All parameters co-optimized in one single optimization

Commanded by three high level parameters

- CPG amplitude
- CPG frequency
- Trunk angle reference

Hole stepping

The CPG can modulate the step length and frequency, and so the robot speed. **Stepping over a hole** is then achieved through CPG modulation.



Acknowledgment & References

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