NEURO-MUSCULAR CONTROLLER BASED ON REFLEXES AND A CENTRAL PATTERN GENERATOR TO ACHIEVE GAIT MODULATION

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Abstract

The aim of this project is to achieve human-like walking on a humanoid robot, by recruiting muscles controlled by reflexes and a central pattern generator.

Keywords: biped locomotion, bio-inspiration

1. REFLEX-BASED APPROACH

The key principles, mainly inspired from [2], are the following. Motors low-level controllers receive torque references generated by virtual Hill-type muscle models [3]. Neuronal signals, called stimulations, control these muscles with a set of reflex rules (feed-back components). The whole controller is then optimized in a simulation environment called Robotran [4], before being transferred to the real robot.

Using the approach of [2], we managed to achieve a 50 steps walk experiment with COMAN, a child-sized humanoid robot (see ***Figure 1***) [6]. Because this controller does not provide lateral stabilization rules (i.e. 2D walking controller), we developed a special upper body controller such that a human operator could provide lateral stabilization to the robot walking on a treadmill, without affecting its motion in the sagittal plane.

As can be seen in ***Figure 1***, some human-like features like stretched stance leg and rolling feet at foot push-off can be observed. These features are usually not encountered on humanoid robots, mainly due to singularity issues. However, we got some discrepancies compared to the optimized simulation gait, like non-stretched leg at the end of the swing phase. This swing leg issue also affected the resulting step length, frequency and the foot strike position. However, despite these huge differences between the optimized and the resulting gait, the robot still managed to walk, demonstrating some robustness inherent to this kind of controllers. We are currently working on solving this swing leg issue.

2. EXTENDING CONTROLLER WITH CPG

In parallel, we incremented the controller of [2] by the addition of a central pattern generator (CPG, a feed-forward component) [1], to achieve gait modulation in simulation. In 2D, this modulation is obtained through the modification of five key parameters like the CPG frequency and amplitude. All these parameters are simply updated linearly as a function of the target speed. Using this approach, we managed to get speed modulation in a range from 0.4 m/s to 0.9 m/s, similar to the human one when scaled to the robot size. Modulation of these key parameters resulted in continuous adaptation of the steps length and frequency. This result was obtained with a single optimization, such that all parameters were co-optimized at once [5].

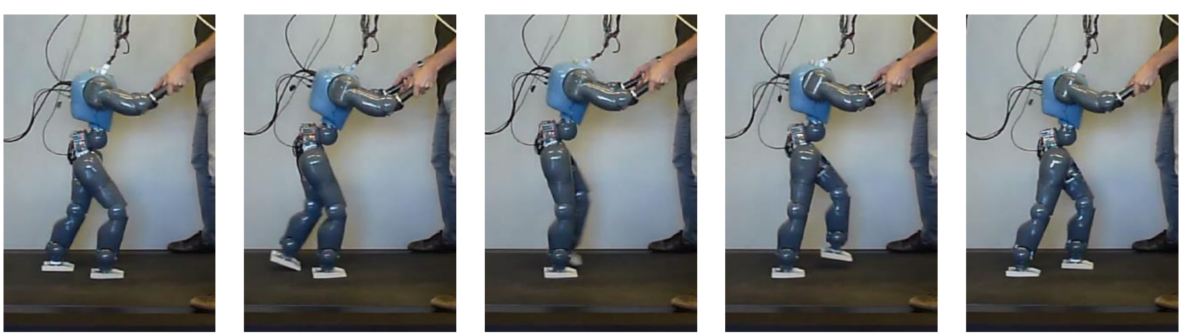

Figure 1: COMAN robot performing a 50 steps walk experiment on a treadmill, while receiving lateral stabilization from a human operator.

We recently extended this approach to 3D scenarios, i.e. when no lateral constraint is applied on the robot. This was done by incrementing both the reflex rules and the CPG structure. New muscles were also added to control the non-sagittal degrees of freedom. Thanks to this, we managed to achieve steering control, on top of the forward speed modulation. An example of steering behavior is presented in ***Figure 2***.

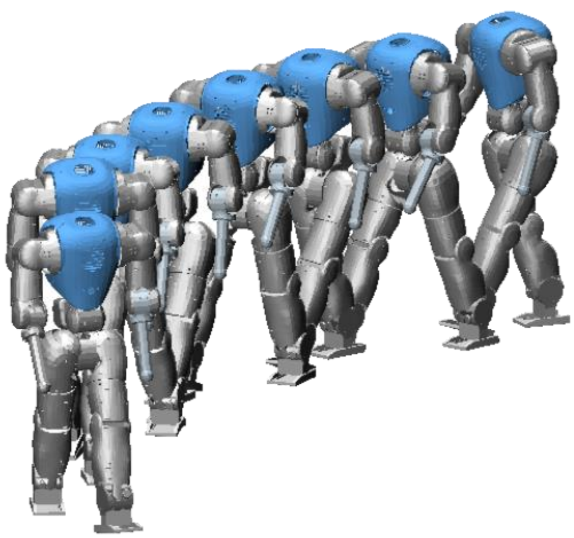

Figure 2: COMAN in simulation environment turning to its left side.

3. CONCLUSION

Compared to traditional humanoid controllers, these neuro-mechanical approaches generate gaits closer to the human ones, with higher speeds and lower energetic consumption. While the offline optimizations are computationally intensive, the controller computational cost during locomotion is way cheaper than the traditional inverse-dynamics based approaches. Finally, these bio-inspired controllers offer interesting possibilities to get a better understanding of real humans' locomotion.

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