Neuro-Muscular Controller Based on Reflexes and a Central Pattern Generator to Achieve Gait Modulation

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

**Experimental Setup for 2D Cases**

Due to the lack of lateral balance control in 2D scenarios, an extra upper body controller is developed to let a human operator provide lateral stability, without affecting the sagittal plane.

**Simulation Gait**

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

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

**Similarities with Simulation**
- Stretched stance leg (feature usually absent in most robotic gaits)
- Rolling foot at swing initiation

**Differences with Simulation**
- Flexed knee during late swing (due to the friction effects in the robot joints)
- Shorter steps
- Lower step frequency

Despite these huge differences 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 simple non-rhythmic input signals. A full range of speeds (0.4 m/s to 0.9 m/s) can be obtained by coupling the reflexes to a CPG. All parameters are co-optimized in one single optimization.

**Combing Reflexes with a CPG**

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

**Speed Control Parameters**

- CPG amplitude
- CPG frequency
- Trunk angle reference

**Steering Modulation in 3D**

The controller is incremented so that the robot motion can be controlled online in a 3D environment.

**Extension to 3D Scenarios**
- Release lateral constraints
- Increment both reflex rules and CPG structure

**Control with Two Joystick Axes**

- Speed control in a range similar to the one obtained in 2D
- Steering direction (left or right) and radius

**Comparison to Traditional Controllers**

- Intensive offline optimizations, but cheap computation during locomotion
- Gaits closer to human ones
- Higher speeds
- Lower energy consumption

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