Walking3LP: A framework to simulate human walking

In this document, we describe the walking animation framework in terms of functionality, publications, economic potential, applications and industrial sectors concerned.

Functionality: This software is designed to simulate different human walking conditions. The main components involved are:

- Walking model: Equations describing the underlying walking mechanics.
- Walking controller: A module to stabilize the locomotion by adjusting footstep locations.
- Walking animation: A conversion method that produces human-like body coordinations.
- Walking gait analysis: A method to predict walking energetics and gait asymmetries.

These components can produce human-like trajectories in steady-state and perturbed walking conditions. They enable the user to change various parameters to modify the behavior:

- Body mass and height
- Walking speed and frequency
- The amount of vertical leg-lift, the angle of the torso and the ratio of double-stance phase
- Terrain inclination angle and constant external dragging forces
- Momentary external perturbations

This framework aims at providing purely closed-form mathematical equations for walking animation. The final performance depends on the hardware configuration of user's computer and the version of Matlab software installed.

Publications: This software is based on a series of publications:

- Walking model: Faraji, Salman, and Auke Jan Ijspeert. "3LP: a linear 3D-walking model including torso and swing dynamics." the international journal of robotics research 36.4 (2017): 436-455.
- Walking controller: Faraji, Salman, Philippe Muellhaupt, and Auke Jan Ijspeert. "Time-projection control to recover inter-sample disturbances, application to bipedal walking control." arXiv preprint arXiv:1801.02150 (2018).
- Human-like animations: Faraji, Salman, and Auke Jan Ijspeert. "Scalable closed-form trajectories for periodic and non-periodic human-like walking." arXiv preprint arXiv:1803.10048 (2018).
- Estimation of energies (not available online): Faraji, Salman, Amy Roning Wu and Auke Jan Ijspeert. A simple model of mechanical effects to estimate metabolic cost of human walking, under review in Nature Scientific Reports, 2017.
- Robotics application: Faraji, Salman, Hamed Razavi, and Auke Jan Ijspeert. "Push recovery with stepping strategy based on time-projection control." arXiv preprint arXiv:1801.02151 (2018).

The underlined publication overviews the entire framework and should be cited.

Economic potential, applications, and industrial sectors: This software is released initially as an academic tool to study bipedal walking mechanics. However, the methods and tools developed could be used in:

- Computer graphics: The closed-form equations of this software can produce natural walking motions for multiple subjects at the same time while providing orders of magnitude faster simulation speeds compared to other physics-based engines.
- Rehabilitation: The generated trajectories and biomechanical predictions can inspire biomechanists to predict certain walking conditions and easily predict quantitative effects which might need extensive and costly human experiments to obtain.
- Robotics: Certain components in this software (the model and controller) were initially developed to control a humanoid robot. This framework, therefore, provides tools to generate human-like trajectories for a humanoid robot as well as stabilization techniques that make it walk robustly.

Given these areas of application, this software may be useful in computer game industry, computer animation film industry, medical rehabilitation centers, fitness programs and robotic companies.

Salman Faraji and Auke Ijspeert
25 April 2018
EPFL