Humanoid Collision Reflex Sequences based on an artificial Robot Nervous System including Contact Location and Direction

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I. Introduction

Reflexive motions have proven to be a valuable tool for preventing damage from robotic arm manipulators and also humanoids to prevent robot falls. Up to now, proprioceptive sensors like accelererometers, gyroscopes and force-torque-sensors were mostly used to generate characteristics like zero moment point (ZMP), Center of Pressure (CoP), tilt angle or velocity of robot links or corrected Capture Point (CCP) [1], [2], [3]. Reflex reactions such as freeze, steps or safe falling motions are activated based on rather heuristic classification or thresholding [1]. These approaches, however, gain information only from the caused effects of disturbance forces rather than from contact properties themselves. Reflexes on the humanoid "Cog" where triggered using the superposition of biologically inspired predefined postural primitives [4].

In this paper, we extend the *artificial Robot Nervous System* (aRNS) framwork [5] to humanoid robots. This makes it possible to use exteroceptive and interoceptive information for designing capable reflex movements.

II. Humanoid Reflex Control

The contact dynamics between any suitably controlled humanoid (via the desired torque $\boldsymbol{\tau}_d$) and a colliding object with state $\boldsymbol{x}_c$ are determined by the generalized coordinates $\boldsymbol{q}$ and the vector of generalized external forces $\boldsymbol{\tau}_{ext}$ that is caused by the contact wrench $\mathscr{F}_c$ or stress σ_c (single point contact) acting on the collision object and the humanoid, respectively, see Fig. 1.

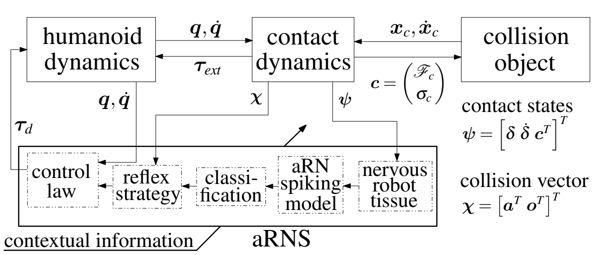

Fig. 1. Adaption of the aRNS to humanoid robots, see [5].

The aRNS for humanoids is split into five parts: the *nervous robot tissue*, the *aRN spiking* model, the *classification*, the *reflex strategy* and the *control law*. Collision severity is represented by the firing rate of the artificial Robot Neurons (aRNs) depending on penetration depth δ, velocity $\dot{\delta}$ and σ_c. The contacts are then classified by suitable algorithms into the classes: *soft*, *light*, *moderate* and *severe*. Note that other schemes are obviously possible as well. In correspondence to these classes and based on collision location $\boldsymbol{a}$ and orientation $\boldsymbol{o}$, we design different context dependent reflex strategies, see Fig. 2.

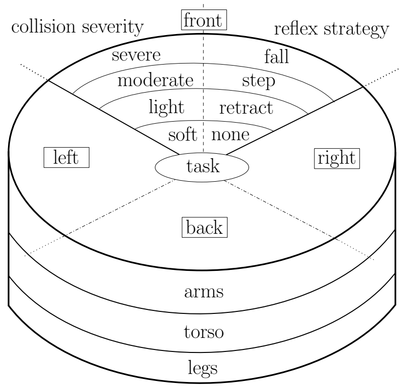

Fig. 2. Humanoid reflex stack.

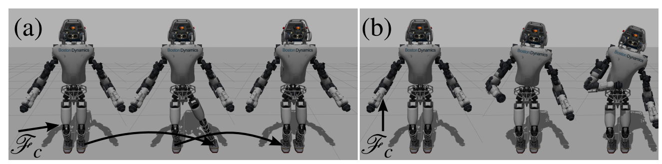

Fig. 3. (a) Moderate collision at the right knee and according reflex reaction. (b) Light collision at the right arm and according reflex reaction.

III. Example

The reflex movements are visualized using a dynamic simulation model of the Atlas robot. Two examples of possible collisions and according reflex movements at the leg and the arm are shown, see Fig. III.

In Fig. III (a), one moderate contact at the right knee results in a step to the left away from the contact direction. In Fig. III (b), one light contact at the right lower arm leads to a retraction of the upper body and weight-shifting to the left leg, away from the collision.

References

[1] O. Höhn and W. Gerth, "Probabilistic balance monitoring for bipedal robots," *The International Journal of Robotics Research*, vol. 28, no. 2, pp. 245–256, Feb 2009.

[2] Atkeson *et al.*, "No falls, no resets: Reliable humanoid behavior in the DARPA robotics challenge," in *Humanoid Robots (Humanoids), 2015 IEEE-RAS 15th International Conference on*, 2015, pp. 623–630.

[3] J. Pratt, J. Carff, S. Drakunov, and A. Goswami, "Capture point: A step toward humanoid push recovery," in *Humanoid Robots, 2006 6th IEEE-RAS International Conference on*. IEEE, 2006, pp. 200–207.

[4] M. M. Williamson, "Postural primitives: Interactive behavior for a humanoid robot arm," *Society for Adaptive Behaviour*, 1996.

[5] J. Kuehn and S. Haddadin, "An artificial robot nervous system to teach robots how to feel pain and reflexively react to potentially damaging contacts," in *accepted at: IEEE Robotics and Automation Letters*, 2016.

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