Reflexive Control of Functional Electrical Stimulation for Spinal Cord Injury Rehabilitation

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RUNBOT is a bipedal robot which operates through reflexes without using a central pattern generator or trajectory planning algorithms [1, 2], Figure 1(a). Ground contact information from the foot is used to activate motors in the opposite leg, generating a gait cycle visually similar to that of humans. But could reflexive control also be applied to humans to generate walking?

A study of load dependent reflexes and their role in the control of human walking will determine whether a gait pattern can be generated using a feedback loop driven by ground contact information from the feet. The aim is to establish a method of controlling functional electrical stimulation (FES) for use in spinal cord injury (SCI) rehabilitation to assist in a patient's gait capability. By incorporating feedback control the device should allow gait cycle modifications to suit the loading conditions.

Ground contact information from the feet and leg muscle activity (EMG) during varying speed treadmill walking was recorded from ten healthy subjects to determine the feasibility of the approach. The treadmill was programmed to change speed automatically in a sequence to remove the correspondence of any identified correlation between foot contact and EMG with walking speed, Figure 1(b).

Adaptive filtering was used to identify the unknown transfer functions which translate the contact information into muscle activation signals. The filter was trained by using the heel contact information as an input and the EMG activity as the output.

Results show a causal correlation between ground contact information from the heel and muscle activity. The derived transfer functions were applied to the RunBot to establish the proof of concept. The transfer functions which produce muscle activation signals relating to flexion and extension of the hip and knee joints in humans were used to drive motors controlling RunBot's hip and knee and were triggered by an impulse signal from foot switches. The gait cycle produced during level walking was stable and controlled which is an indication that the transfer functions may be suitable for use in an FES control system to aid in the rehabilitation of patients with spinal cord injuries.

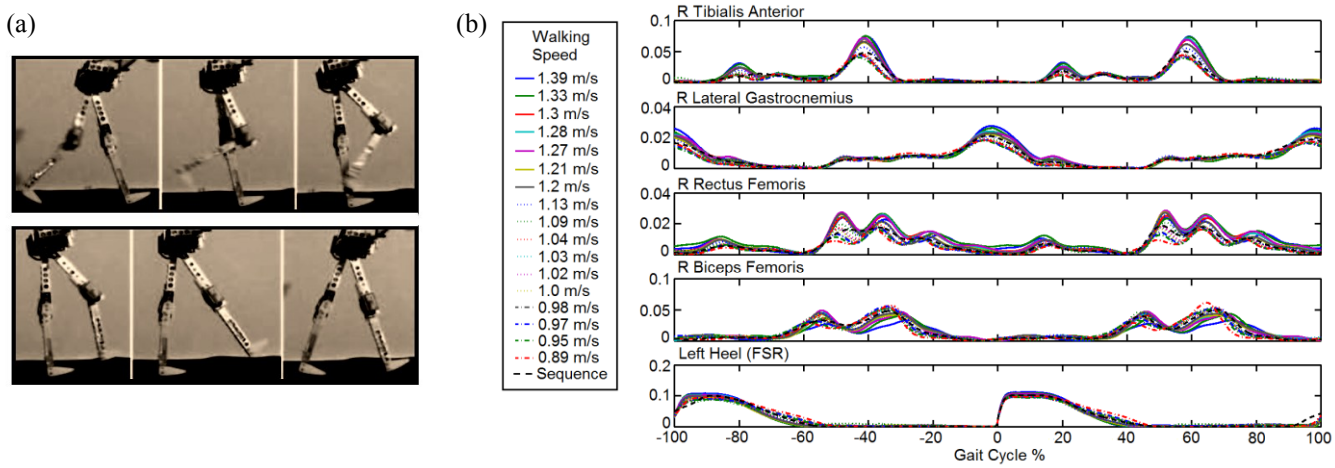

Figure 1: (a) RunBot [2]. (b) The EMG signals (right leg) were event related averaged in a time period of one gait cycle before and after left heel contact and demonstrate the relationship between heel contact and muscle activity. Increasing walking speed increases the amplitude of the EMG signal.

REFERENCES

[1] T. Geng, B. Porr, and F. Worgotter, " Fast Biped Walking with a Sensor-driven Neuronal Controller and Real-time Online Learning," Int J Rob Res, vol. 25, no. 3, pp. 243-259, 2006a.

[2] P. Manoonpong, T. Geng, T. Kulvicius, B. Porr, and F. Worgotter, "Adaptive, Fast Walking in a Biped Robot under Neuronal Control and Learning," PLoS Comput Biol, vol. 3, no.7, pp. 1305-320, 2007.

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