GENERATING ELECTROMYOGRAPHIC PATTERNS OF ANKLE MUSCLES DURING WALKING

Sook-Yee Chong, Heiko Wagner
Motion Science, University of Münster, Germany
email: sy.chong@uni-muenster.de
web: www.uni-muenster.de/Bewegungswissenschaft

INTRODUCTION

Gait patterns are made up of oscillatory motions. Neural oscillators, known as central pattern generators (CPG) may play an important role in generating these rhythmic movements [1]. Therefore, the aim is to develop a CPG model that could predict electromyographic (EMG) signals at the ankle joint during walking from measured ground reaction forces (GRF).

METHODS

A simple Matsuoka oscillator [2,3] consisting of two neurons was used to generate EMG signals of the tibialis anterior (TA) and soleus (Sol). The neurons are mutually inhibited, i.e. when one neuron is activated, the other is suppressed. Therefore, this activity would act like two antagonistic muscles at the ankle joint.

The oscillator was governed by the following equations:

$$Tr_i \dot{x}_i + x_i = -\sum a_{ij} y_j + s_i - b_i f_i$$

$$Ta_i \dot{f}_i + f_i = y_i$$

$$y_i = g(x_i - \theta)$$

$$g(x_i) = \max(0, x_i)$$

where *Tr* is the rise time constant which determines the rise time when given an input signal, *Ta* is the adaptation time constant which determines the time lag due to the adaptation, *x* is the inner state of the neuron, *y* is the generated output of the neuron, *s* is the input signal, θ is the threshold above which an output is generated, *f* is the degree of fatigue or adaptation in the neuron, *b* determines the firing rate for the input, *a* is the weight of inhibitory connection between neuron i=1 and neuron *j*=2 [2,3].

The vertical GRF was used to determine the signal input in the following step function:

$$\dot{p} = r(GRF - p)$$

The signal input was thus calculated as:

$$s_i = w_i . p + v_i . \dot{p}$$

where *w* and *v* represented the weights of each excitation.

The outputs were compared with EMG measurements collected from the TA and Sol during walking.

Matsuoka [2,3] had set certain conditions in which the parameters for the oscillator can successfully generate an output. The values were chosen manually such that they would produce the best fit to experimental data.

RESULTS AND DISCUSSION

The period in which the Sol was activated during gait was shorter compared to experimental data (Figure 1). Attempts to increase this activation period often resulted in the change in the frequency and amplitude of the output. This will in turn, resulted in a gait shift i.e. the Sol started to activate when it should be silent during swing. It is possible that another input signal is needed during the transition from stance to swing.

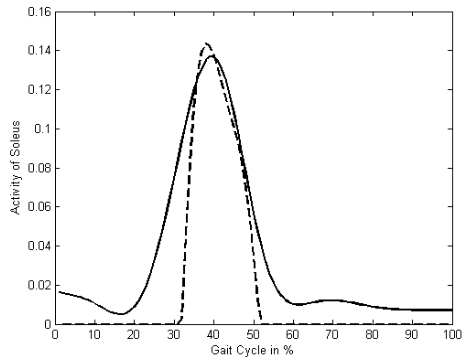

Figure 1: Comparison between the EMG activity generated by the oscillator (dashed line) and EMG measurements (solid line) of the Sol.

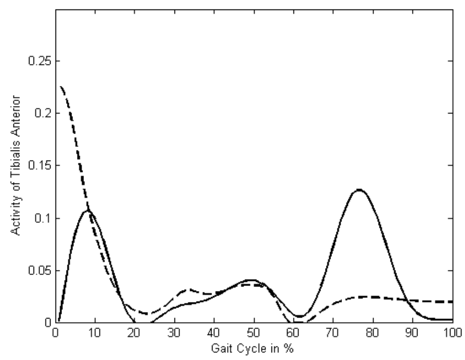

Figure 2: Comparison between the EMG activity generated by the oscillator (dashed line) and EMG measurements (solid line) of the TA.

The TA should be activated during swing phase to clear the foot during swing. However, the resulting output during swing did not fit experimental data. Considering that the average foot clearance is 2 cm and done almost unconsciously, it was postulated that another input signal is necessary. A peripheral input might be needed in the model to induce an activity of the TA during swing. There is also more than twice the activation in early stance. Perhaps, a specific signal input responsible for phase transition is needed in the oscillator.

It should be noted that neural circuits do not necessary represent variables that will result in producing GRF. However, these results are a first step in demonstrating that the GRF could induce muscle activation at the ankle joint during walking, though it is not necessarily the only input. The future plan is to investigate additional signal inputs and the effects on other joints.

REFERENCES

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