THE FEASABILITY OF REFLEXIVE CONTROL IN TRANSFEMORAL PROSTHESES

E.C.Wentink[1], J.S. Rietman[1,2], P.H. Veltink[1]

[1]University of Twente, Department of biomedical signals and systems, Netherlands

[2] Roessingh Research and Development, Netherlands

1 Introduction

In daily life of a transfemoral amputee (TFA) a stumble or a fall is not uncommon, mainly due to the lack of feedback and control of their prosthesis. Although intelligent knees are now available, proprioceptive feedback and control over the lower leg is needed. Using muscle activity (EMG) as control input and providing artificial feedback is a concept already seen for upper extremity prosthesis, but not for the lower extremity. Ideally this feedback also triggers the reflexes of the prosthetic user, for the prosthesis to become second nature to the user. This article will address the allowed time delays in a system where reflexes and EMG are used to control a transfemoral prosthesis. The response to a knee-unlock was analysed in a modeling study, including the reflex loop and EMG control, to determine the maximal time delays which still allow a stable control of the knee.

2 Methods

The model is designed to simulate a person landing on an unlocked knee at the end of the swing phase in walking. In the model the human body is assumed to be a point mass supported by the upper and lower leg, modeled as mass less segments. The ankle joint is fixed, but the lower leg can pivot freely around this point. The knee is a freely moving hinge, between upper and lower leg. The point mass, full body weight (80kg), is also moving as a pendulum around the ankle joint and is given an initial velocity. The mass lands on an unlocked knee, to mimic the moving body landing on the non-locked knee. The knee angle, the deviation from a stretched leg, serves as an input measure for artificially applied feedback. The CNS then determines if reflexive action is needed and if so the subsequent EMG can be measured. The knee angle is controlled inside the knee by a spring and by a moment generator, which generates a fixed moment between 50 and 300Nm, if EMG activity surpasses a threshold. The knee was considered stable if the angle did not exceed 40 degrees and the total moment around the knee did not exceed 300Nm[1].The allowable time delay in the loop, between the perturbation and the control input to the knee, whereby the knee is within the stability margins is assessed to determine the feasibility of reflexive control of transfemoral prosthesis.

3 Results

A moment generated around the knee of 50Nm, allows a time delay of about 60ms in the system. For larger moments this increases to 80-130ms (see Fig.1). The initial contribution to the knee stability of the EMG controlled moment generator, with respect to the spring stiffness, also slightly increases with an increase in moment. The max knee moment was never reached.

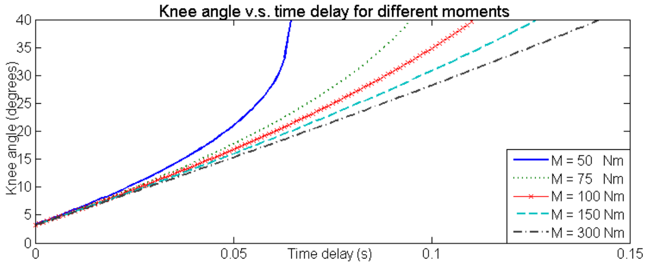

Figure 1: Relation of the maximum knee angle to the time delay at different moments generated at the knee.

4 Discussion

The whole process of sensing, artificially triggering feedback, EMG detection and prosthetic actuation will take at least 100ms[2,3], this is the minimal allowable time delay in the system. This implies that the moment to be generated around the knee in case of a knee unlock must be at least 100Nm for the concept to provide useful contribution to prosthetic control. The model is however a simplification of reality and it may proof hard to realize. Nevertheless, if an effective reflexive reaction can be triggered the prosthetic user may become more aware of any unforeseen situation.

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