

# ANALYSIS OF TRANSFEMORAL PROSTHETIC GAIT USING KNEE JOINT WITH/WITHOUT STANCE CONTROL FUNCTION USING FORWARD DYNAMICAL SIMULATION

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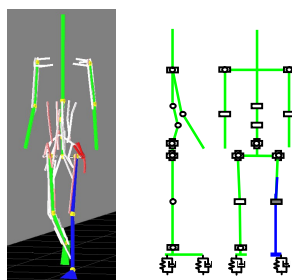
## INTRODUCTION

Knee joint prostheses have advanced greatly in the last two decades. In particular, the C-leg (Otto bock) is one of the most innovative products for above-knee prosthesis users because of its reliability, especially in the stance phase. The knee joint prevents knee buckling using sensors that detect the walking phase and a hydraulic actuator controlled by a microprocessor. The stance-phase control function of the knee joint improves walking stability, which eliminates the users' fear of falling. However, the efficiency of this function is not clear. Since prosthesis users are typically used to wearing their prosthesis in daily living and are not able to adapt to a new prosthesis function during a short experiment, a simulation study can be used to resolve this problem as trial conditions are easier to manage.

We developed a forward dynamic simulator that generates human walking motion [1]. In this study, transfemoral prosthetic walking motion was simulated and we compared the difference in walking motion and its properties between knee joint prostheses with and without the stance control function.

## METHODS

The simulation model is based on a three-dimensional (3D) neuro-musculo-skeletal human model [2]. Figure 1 shows the model with a transfemoral prosthesis as the left leg below the mid-femur. The human model consists of 20 neural oscillators, 61 muscles, and 13 rigid links. In this study, the stance control function of the knee joint was modeled as generating a braking torque when the foot contacts the ground. Prosthetic knee joints with (current knee joint) and without (conventional knee joint) this function were modeled.



**Figure 1:** A general view of the model of an amputee with a transfemoral prosthesis. The human model consists of neural, muscular, and skeletal components.

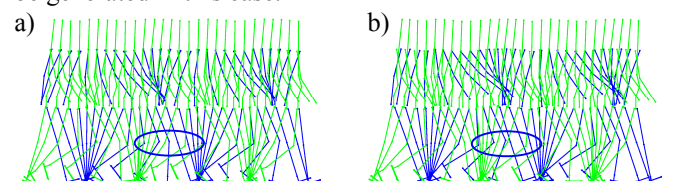
The model generates walking motion after optimizing neural parameters using an objective function ( $OF$ ) defined as  $OF = 1.0/(S + \alpha R)$ , where  $S$  is the specific power (total energy consumption per unit walking distance),  $R$  is the roughness of the whole-body motion (sum of the rates of change in muscular activation throughout the body), and  $\alpha$  is a weighting coefficient. We assume that walking with a higher

value of the  $OF$  is better. Using the genetic algorithm, the parameters of the neural model and initial conditions are searched as an optimization problem to maximize the  $OF$ . In this simulation, 16 steps was the limit of normal walking and the  $OF$  evaluated walking from step 6 to 10. After a 200,000-iteration optimization process, more than 16-step walking motions were generated using each knee joint model.

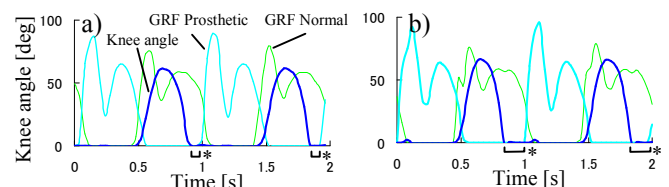
## RESULTS AND DISCUSSION

Figure 2 shows the walking motion generated using knee joints with (a) and without (b) the stance control function. The blue and green lines indicate the limbs ipsilateral to the prosthesis and other body segments, respectively. Both motions are at similar walking speeds (approx. 1.3 m/s). Figure 3 shows the prosthetic knee joint angles and ground reaction forces of the normal and prosthetic sides while walking four steps from heel contact by the prosthetic foot, where (a) and (b) are walking with and without the stance control function, respectively.

The prosthetic (blue) knee motion indicated by the circles in Fig. 2 and the time lag until heel contact from knee extension for the prosthetic leg indicated by asterisks in Fig. 3 show that knee extension of the prosthesis without the stance control function is faster in the swing phase. Knee buckling occurs more readily for the prosthesis without the stance control function, and adopted walking is suggested to be generated in this case.



**Figure 2:** Stick figures generated while walking four steps with (a) and without (b) the stance control function.



**Figure 3:** Knee angles on the prosthetic side and the ground reaction forces (GRFs) on both sides while walking four steps, where the walking phase is identified by the patterns of the GRFs.

## ACKNOWLEDGMENTS

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## REFERENCES

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2. Hase K, Yamazaki N, *JSME Int C* **45-4**, 1040-1050, 2002.