A simple approach to simulate lower limb movement during gait

O. SZYMANOWSKA[1], D. GRZELCZYK[2], J. AWREJCEWICZ[3]

Key words: *exoskeleton, central pattern generator, control, gait*

1. Introduction

Dysfunctions of the locomotion system are a common and serious problem observed both in young people and the elderly. Among many causes, one can mention numerous conditions such as spinal cord injury or multiple sclerosis. Nowadays, the locomotion system is usually rehabilitated with the labour-intensive help of physiotherapists. However, it is of great importance to develop devices and methods that would help both the disabled and their therapist. Nowadays, much attention is paid to lower limb exoskeletons, which have been proven to facilitate gait rehabilitation [1, 2]. In the present study, an attempt was made to use a concept of a central pattern generator (CPG) to develop a simple simulation model of human gait. A similar approach has been used, for instance, to produce a tripod gait in a hexapod robot [3].

2. Methods

In the initial stage of the study, gait of a volunteer was observed with the use of a 8-camera OptiTrack motion capture system. To register the linear and angular positions of body segments, 37 passive markers were put on the volunteer's body, following the OptiTrack Baseline protocol. Then, based on the recorded trials, the system was able to reconstruct the changes in positions of all the segments during walking.

Knowing the linear and angular positions of particular segments, it was possible to develop a model that would resemble the trajectory of the heel. The proposed CPG model is based on the sine function. Movement of the lower limb in the direction of the x-axis and z-axis, respectively, is described by variables $X(t)$ and $Z(t)$ – the model considers the motion in the sagittal plane only. The right leg ($X_A(t)$, $Z_A(t)$) and the left leg ($X_B(t)$, $Z_B(t)$) are controlled by the same model, but their periodic orbits are in antiphase (the phase shift equals π). The periodic orbit of the proposed CPG model is shown in Fig. 1.

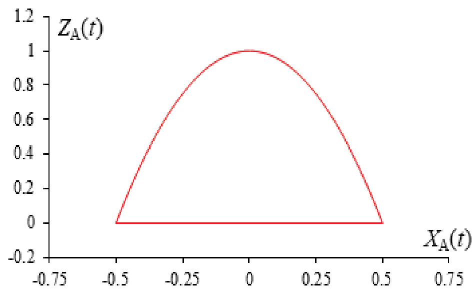

Fig. 1. Phase trajectory of the proposed CPG

[1]Olga Szymanowska, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland,, e-mail: olga.szymanowska@edu.p.lodz.pl

[2]Dariusz Grzelczyk, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland, dariusz.grzelczyk@p.lodz.pl

[3]Jan Awrejcewicz, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland,, e-mail: jan.awrejcewicz@p.lodz.pl

If one uses a chosen trajectory of the heel as input, the trajectories of hip and knee joints can be found with the use of equations of inverse kinematics. Thus, joints of the lower limb can be controlled by using one input signal. The model allows one to control parameters of a single stride by means of changing the frequency and scaling the orbits to convert the variables of the CPG model to the workspace of the exoskeleton (in the local coordinate system).

To check if the proposed CPG model resembles movement of the lower limb during gait, the results of numerical simulations were compared with experimental ones. Figure 2 presents configurations of the human body captured at equal time intervals of a single gait cycle. The upper part of the figure contains frames taken during the experiment while the bottom part comprises simulation results obtained for the same time instants. As one can see, configurations of the lower limbs are similar in both the upper and the lower parts of the figure. The approach has been described also in [4].

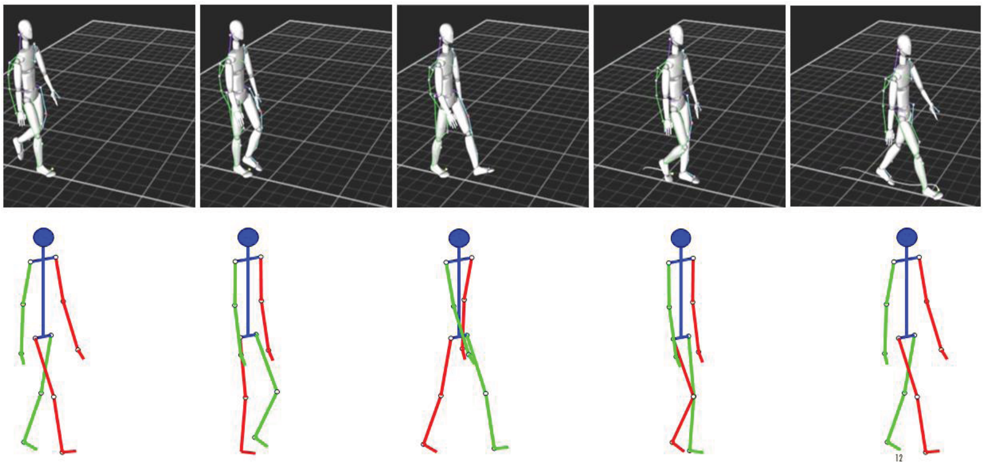

Fig. 2. Comparison of experimental and numerical results (in the simulation, movement of the lower limbs is controlled by the CPG while the positions of the upper part of the body were taken from the experimental data)

Acknowledgments: The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700 for years 2016-2018.

References

[1] AGRAWAL S., BANALA S., FATTAH A., KRISHNAMOORTHY V., SCHOLZ J., WEI-LI H., *Assessment of motion of a swing leg and gait rehabilitation with a gravity balancing exoskeleton.* IEEE Transactions on Neural Systems and Rehabilitation, 2017, 15, 410 – 420.

[2] PETRARCA M., PATANÈ F., ROSSI S., CARNIEL S., CAPPA P., CASTELLI E., A *new robotic exoskeleton for gait recovery.* Gait Posture, 2014, 40, 26 – 27.

[3] GRZELCZYK D., STAŃCZYK B., AWREJCEWICZ J., *Prototype, control system architecture and controlling of the hexapod legs with nonlinear stick-slip vibrations.* Mechatronics, 2016, 37, 63-78.

[4] GRZELCZYK D., SZYMANOWSKA O., AWREJCEWICZ J., *Gait pattern generator for control of a lower limb exoskeleton,* Vibrations in Physical Systems, 2018, 29, 2018007 (10 pages).