

Parametric identification of lower limbs during walking of a man

J. Pauk, K. Jaworek

*Department of Automation & Diagnostics,
Bialystok University, Poland.*

Abstract

The paper presents a new method, which could be used in bioengineering as assessment of walking recovery. The method is identification human gait model. It is based on regression function. The method very accurately represents real data from experiment by model.

1 Introduction

The human body is a mass of complex segments. Walking involves a combination of complex movements of these segments. Computers can't cope with the full complexity of the human body. We therefore have to make assumption to develop a simple model of the movement of the body which the computer can cope with mathematically and which we can understand. Modelling involves quite sophisticated computer programmes. Presented method is based on identification human gait model from power developed by muscle joints. We obtain coefficients of model that determine human movement. Evaluation parameters of gait is helpful in assessing abnormal gait, to quantify improvement resulting from intervention. Authors proposed a ambulatory system which could support decision making in medicine. This system consists from data base of patients, model of norma and model of different pathologies. The main block is identification human gait in this system. This system is useful in several clinical situations to support decision making relate to treatment (rehabilitation, surgical treatment, medicine, etc.) . It provides satisfactory results for normal walking and abnormal gait. We have proposed a new diagnostic tool for gait analysis, which consists from electrogoniometer, digital filter, artificial

network, and identification system. Accuracy of this station depends on measuring data and their biomechanical analysis and interpretation.

2 Methods

Lower limbs movement during walking was measured using ELITE-3D in Centro di Bioingegneria in Milan. It is based on a on-line data processing of signals from a number of TV-cameras. The signals were digitized at a sampling rate of 50 Hz. Kinematics data includes the position, orientation, velocity and acceleration segments. From kinematic data it is possible to calculate force joints, force moments and power. We have analysed ankle, knee and hip powers from two groups of adults: 15 normal and 30 hemiplegic. The markers were put as follows: two on the Posterior Superior Iliac Spines, one on the Sacrum Bone, two on the Lateral Femoral Condyles, two on the Lateral Malleoli, two on the Elbow Epicondyles, one on the Wrist. Each subject performed two trials including seven gait cycle.

The muscles are the active elements controlled by central nervous system. One major problem is modelling large – scale motions is to find appropriate description actuators with accurate mathematical models. Tractable model describe the dynamical properties of power developed by muscle joints. It proved to be practical in numerical applications. The model is determined by identification. The method is based on regression function. Below is presented the method of identification.

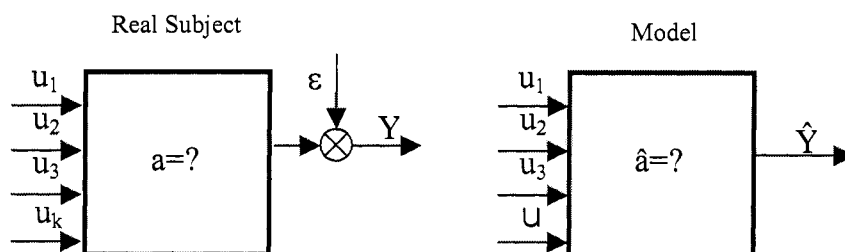


Figure 1: Identification of human gait model.

The power muscle is represented by the vector $\underline{U}_n$ and vector Y_n . Vector $\underline{U}_n$ is model's input in n time before. The vector Y_n is model's output in n time. The best present real data by model we obtained for the model, where the value of power in n time is depends on three value of powers before.

$$Y_n = \underline{U}_n \cdot \underline{a}, \quad (1)$$

$$\underline{U}_n = [Y_{n-1} \quad Y_{n-2} \quad Y_{n-3}], \quad (2)$$

Based on activation dynamics and muscle excitation it is possible to calculate the vector $\underline{a}$, which represent parameters of human gait.

$$\underline{a} = (\underline{U}^T \cdot \underline{U})^{-1} \cdot \underline{U}^T \cdot \underline{Y}, \tag{3}$$

$$\underline{a} = [a \quad b \quad c]^T, \tag{4}$$

where:

- N – sample size,
- Y_n – model’s output (power developed by muscle joints in time $t+1$),
- $\underline{a}$ – parameters of gait,
- $\underline{U}_n$ – model’s input (power developed by muscle joints in time: $t-1, t-2, t-3$).

The two phases: stance and swing of normal and pathological gait have been identify by presented model for classify gait to different groups. The eight subphases include: initial contact, loading response, midstance, terminal stance, preswing, initial swing, midswing, terminal swing have been identify for design system to support clinical decision making.

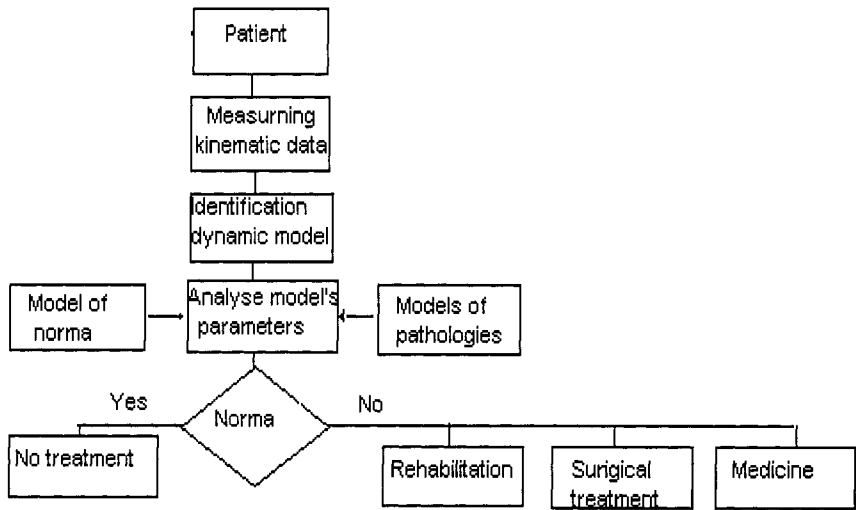


Figure 2: System to support clinical decision making.

We have proposed a new diagnostic station to measuring of human gait. Presented diagnostic’s station can be use to measure kinematics data of human walking in hospitals and clinics.

The main tool is the station is electrogoniometer. The signal from electrogoniometer is low-pass filtered to remove noise. The data were transferred to the computer for analysis. Powers are estimate by neural networks. The parameters from identification represent human gait.

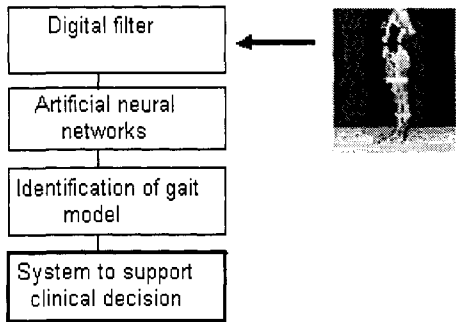


Figure 3: Scheme of diagnostic station.

3 Results

The correspondence between normal walking compared to hemiplegics is shown in Figure 4.

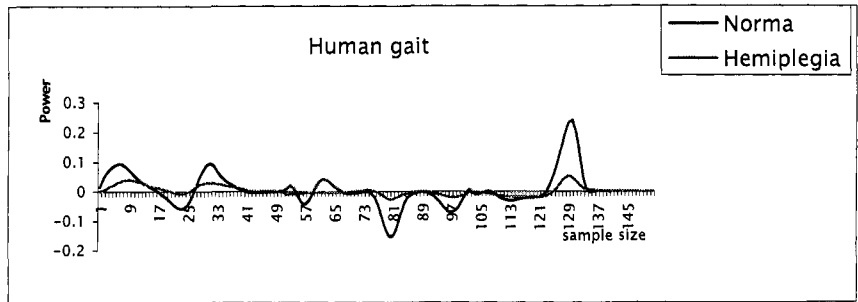


Figure 4: Human movement in normal and hemiplegia.

The parameters of human gait are shown in the following table.

Table 1: Parameters of gait (norma).

Gait cycle	a	b	c
Loading Response	0.6362	-0.0186	0.0464
Midstance	1.2326	-0.3501	-0.0755
Terminal Stance	1.0386	-0.1383	-0.0910
Pre-Swing	0.5757	-0.0570	-0.4084
Initial -Swing	0.6408	-0.0867	-0.0968
Mid-Swing	0.6102	-0.0511	-0.0514
Terminal-Swing	1.2260	-0.2627	-0.1506

Table 2: Parameters of gait (hemiplegia).

Gait cycle	a	b	c
Loading Response	0.8146	-0.2338	-0.1355
Midstance	0.9871	0.0422	-0.1554
Terminal Stance	1.0735	-0.1219	-0.1534
Pre-Swing	0.6889	-0.1086	-0.2875
Initial –Swing	0.6581	-0.0181	-0.1008
Mid-Swing	0.6557	-0.0450	0.0128
Terminal-Swing	1.2534	-0.1946	-0.2360

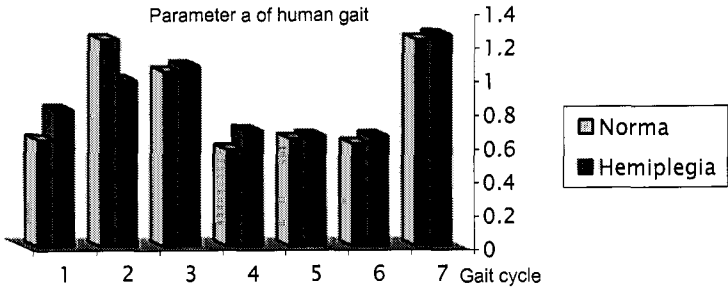


Figure 5: Parameters of human gait.

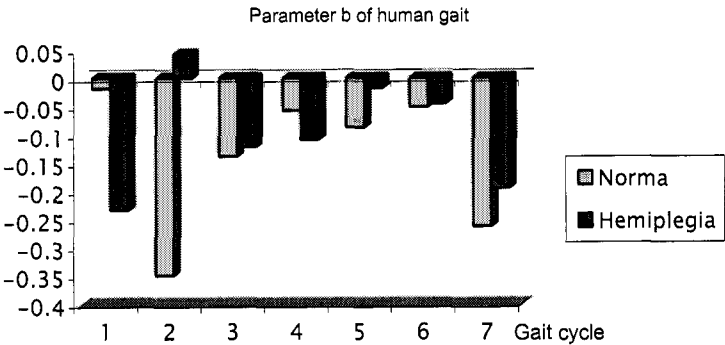


Figure 6: Parameters of human gait.

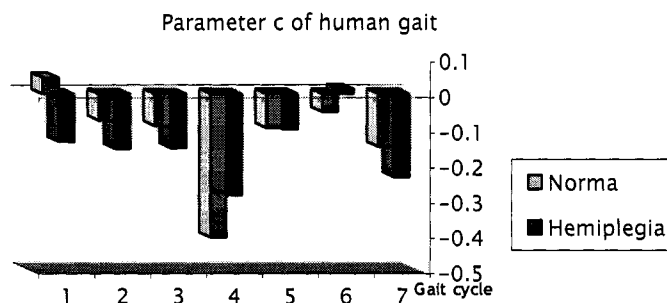


Figure 7: Parameters of human gait.

4 Conclusions

The method of identification of human gait model accurately represents real data from experiment. It is good way to assess human movement in both normal and hemiplegics. It could be used in bioingegnering and clinics to improve the patient's gait. In the future the method will be apply to assessment prosthesis of lower limbs.

References

- [1] Derlatka M., *Method of energetic analysis and assessment of human gait*, IBIB, Warsaw 2002.
- [2] Fischenberg D., *Identification of an unsteady aerodynamic stall model from flight-test data*, AIAA-95-3438-CP, 138-146, 1995.
- [3] Jaworek K., *Methods of evaluation of the power developed in a man's leg during normal walking*, Springer-Verlag, Italy pp. 322-332, 1993.
- [4] Jaworek K., Frigo C., Pauk J., *Power correlation between joints during walking of a man*, Gait and Posture, Vol.14, iss.2, Rome, pp.138, 2001.