The 3rd International Conference on
″Computational Mechanics
and Virtual Engineering″
COMEC 2009
29 – 30 OCTOBER 2009, Brasov, Romania

MODELING THE HUMAN GAIT AND STANDING STABILITY BY *LIFEMODE* SOFTWARE

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Abstract : *In this paper we presented some theoretical and practical considerations concerning human motions modeling using dedicated software and modeling-simulation mechanisms. Thus in the first part of the paper we developed the theoretical aspects of the gait cycle and human body stability. In the second part we presented the modeling stages by LifeMode software, of the gait cycle for persons with neuro-motor disabilities by comparison to the normal gait cycle or stability behavior. In the third part the conclusions of this human gait modeling procedure are shown*
Keywords: *modeling, gait, biomechanics, software LifeMod*

1. INTRODUCTION

The computer analysis of the human motions emphasizes a series of features of the gait cycle concerning the forces developed at the contact support, the duration, the forces developed in the joints, velocities, displacements or spatial positioning of different parts of the human body.
Humans possess a unique physical structure that enables them to stand up against the pull of gravity.
To build a model of interaction of human body it is necessary to understand its component parts, the biggest part of the human body is the trunk; comprising on the average 43% of total body weight. Head and neck account for 7% and upper limbs 13% of the human body by weight. The thighs, lower legs, and feet constitute the remaining 37% of the total body weight.
There are 206 bones in the human body and almost all bones are facilitators of movement and protect the soft tissues of the body. The frame of the human body is a tree of bones that are linked together by ligaments in joints called articulations.

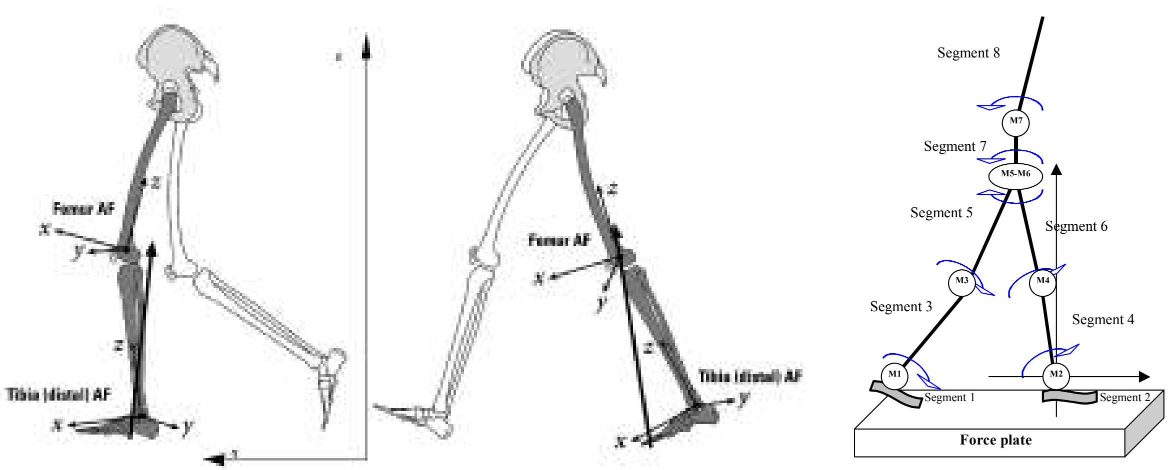

Figure 1 Forces developed along the human gait and the locomotor system segments involved in the motion [1]

Skeletal muscles act on bones using them as levers to lift weights or produce motion.
In the human body each long bone is a lever and an associated joint is a fulcrum, acting like a lever which can alter the direction of an applied force, the strength of a force, and the speed of movement produced by a force in moving. [2]

The walking model includes three body parts: an upper link, a lower link, and a foot [3].
Two joints are represented by the hip and the ankle, the lower and upper links represent the leg and the upper body of the human, respectively and the sources of movements are joint torques and thrust force.

2. THEORETICAL ASPECTS OF HUMAN BODY MODELING PROCESS

This model was used to simulate human walking in the sagittal plane during the weight acceptance phase, that is, the time duration from heel contact to the middle of the single leg support phase. The equation of motion of the model consists of two parts: the rotational dynamic of the two links and the moving dynamic of the foot. The equation of motion of the links is expressed as follows:

$$[M]\ddot{\theta} = [N]\dot{\theta}^2 + [G] + \tau + F_{TH} \quad (1)$$

where [M] is the mass and inertia matrix; [N] is the Coriolis and centrifugal force matrix; [G] is the gravitational force; τ is the matrix of torques angles and F_{TH} is the thrust force.

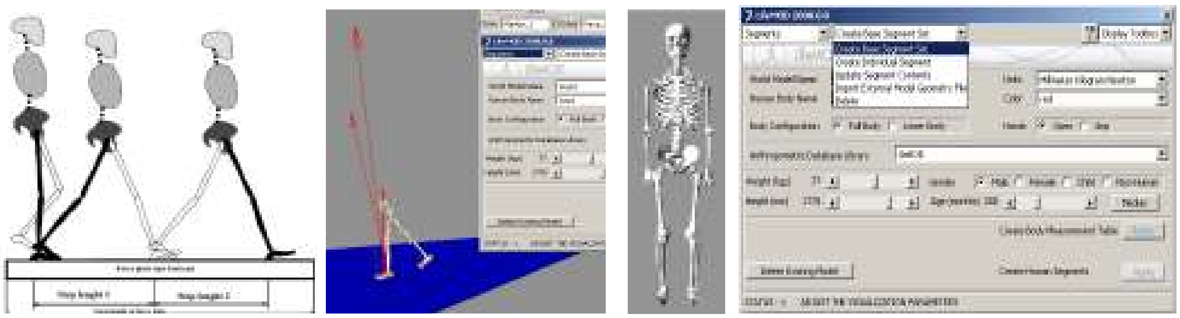

Figure 2 Used locomotor system model by *LifeMod* software

Starting from a pre-defined skeleton module and considering the anthropometrical database NASA-STD-3000 we build the shape of the human inferior locomotion system with direct contact to the walking support.
For modeling human gait we considered a series of data connected to motion, trajectory, velocity or acceleration but at the same time we introduced the boundary values of the gait type (normal, malfunction of the right or left foot, jumps or steps, slips or sliding on plane surfaces etc.). The modeling stages aim at introducing data both for the normal mode and for the one used to model a certain gait type in order to simultaneously visualize these differences.
In fig.3 a block diagram is presenting the steps in which these methodology of human gait and standing stability modeling are fitting the marker configuration, analyze and calculate kinematics, calculate kinetics, study control strategies and simulate human walking or standing stability using experimental data and the model created.

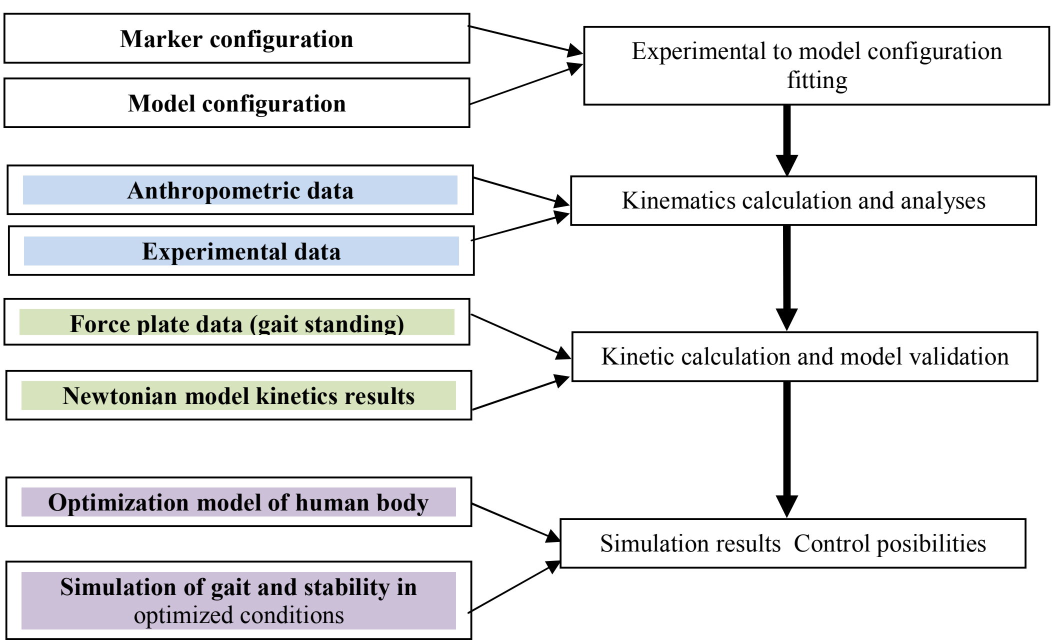

Figure 3 Diagram of the human body gait and stability analysis model

3. MODELING STRUCTURE

For modeling human gait we considered a series of data connected to motion, trajectory, velocity or acceleration but at the same time we introduced the boundary values of the gait type (normal, malfunction of the right or left foot, jumps or steps, slips or sliding on plane surfaces etc.). The modeling stages aim at introducing data both for the normal mode and for the one used to model a certain gait type in order to simultaneously visualize these differences.

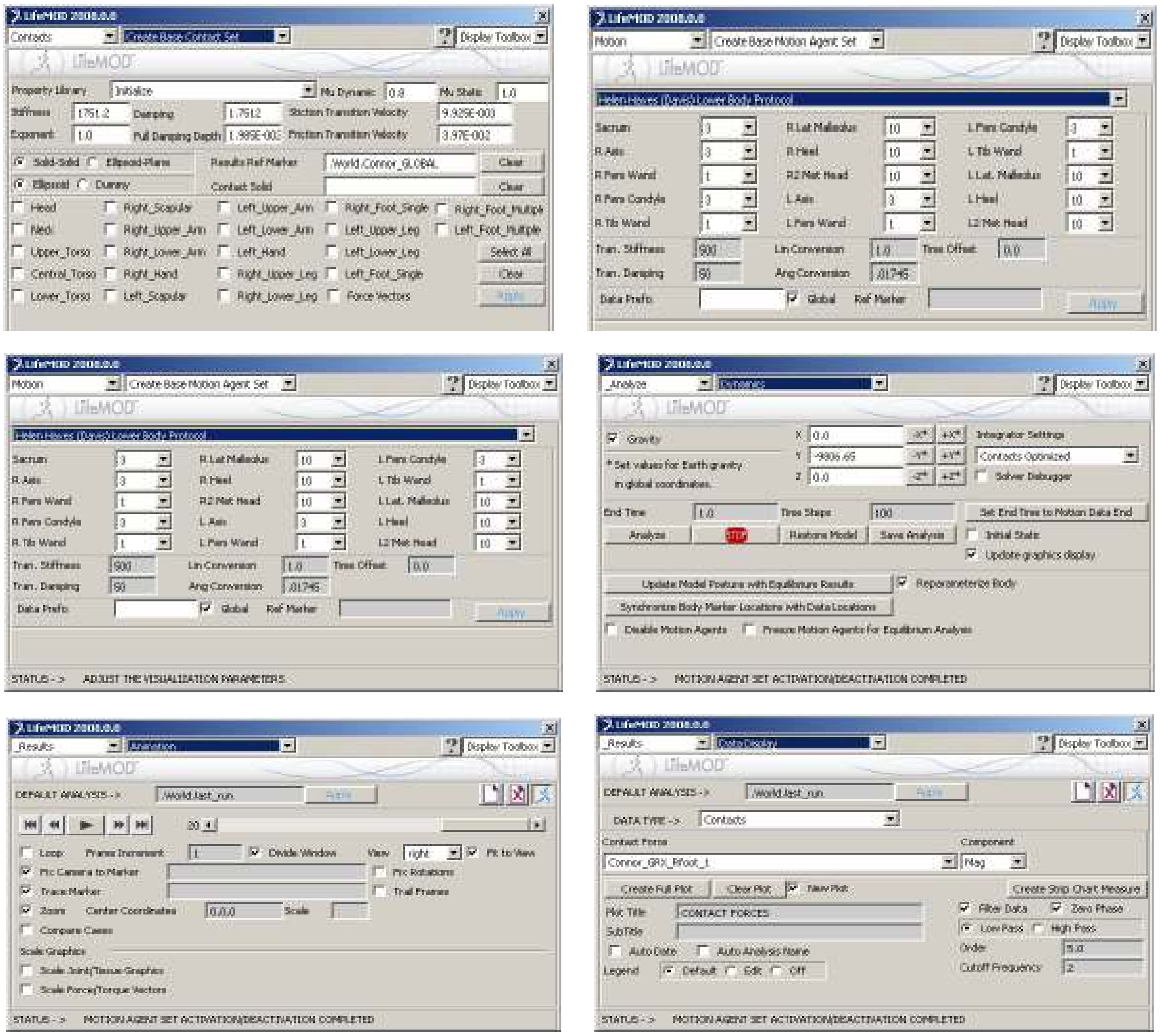

Figure 4: Stages of accomplishing the gait process modeling, simulation and visualization

Following the analysis of different modeling alternatives created by software *Life*MOD, in a normal way and with imposed disabilities we discovered a series of aspects correlated with the results obtained during the investigations upon a human subject in the same conditions. These investigations and recordings, obtained by help of a force and moments acquisition system along three directions (Kistler force plate) confirm the shape of the contact force (between feet and displacement surface) variation.

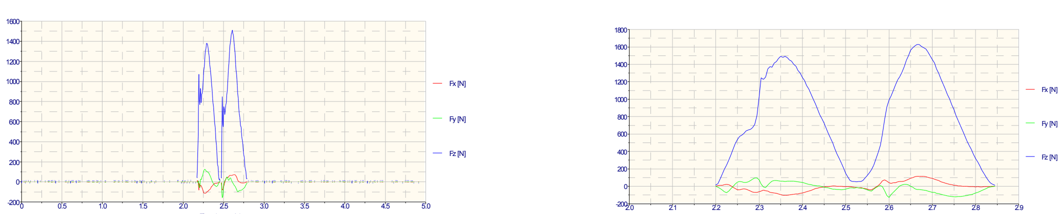

Figure 5. Recordings of the gait cycle for two subjects with different weights and gait styles (attack by heel respectively with the tip of the right foot)

Thus, for a quick response in the analysis of the gait type and forces developed in the subject locomotion system, the created model can estimate and correlate data at different recording times and respectively for different anthropometrical dimensions or mobility restrictions.
From the recordings performed using the experimental device, the most important is the evolution of the contact force between the foot and support, considering no sliding between them and which emphasize the precise moments when this contact takes place.
The stability of the analyzed subjects was recorded with the same system and compared to the one modeled by LifeMOD software, comparison that emphasized a series of aspects connected to the influence of the contact between the foot and the support but also to the feet muscles structure.

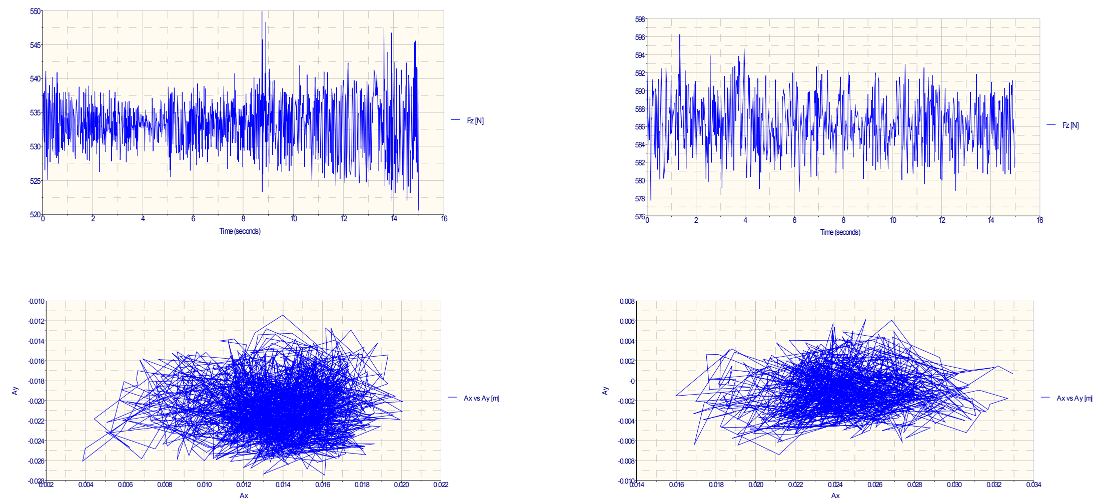

Figure 6 Graphic representation of the weight variation (vertical direction) and of the stability area for two subjects with different weights and muscle structures (female, male)

4. CONCLUSION

In these simulations, muscles generated about half (57±74%) of the knee extension acceleration during the extension phase and the other half was provided by velocity-related forces that arose from the rotational motions of the limb segments. Muscles generated nearly all of the knee flexion acceleration during the braking phase. Muscles on the stance limb, particularly the hip abductors, extensors, and flexors, had a major influence on motions of the swing-limb knee in the simulations. These muscles, in combination with their induced ground reaction forces, accelerated the pelvis, simultaneously inducing reaction forces at the swing-limb hip that accelerated the thigh and knee.
The modeling and simulation structure, briefly presented for this case represents the subject of a more extended research, which allows the developing of an investigation-assessment-rehabilitation protocol for the hip implant patients.

5. ACKNOWLEDGMENTS

Researches are part of Grant *PNII-Idei* 722 and 744 with CNCSIS Romania and the investigations were developed using equipment belonging to the Research Platform CAPACITATI, University Transylvania Brasov.

REFERENCES

[1] A.G. Schache, R. Baker, C.L. Vaughan *Differences in lower limb transverse plane joint moments during gait when expressed in two alternative reference frames.* Journal of Biomechanics 40 (2007) 9–19
[2] A. Tözeren, Human *Body Dynamics Classical Mechanics and Human Movement*, ISBN 0-387-98801-7 Springer-Verlag New York
[3] Baritz M., Cotoros D., Cristea L., Rogozea L., *Assessment of human bio-behavior during gait process using LifeMod software*, ACTA UNIVERSITATIS APULENSIS, no.18/2009
[4] Woo-Hyung Park, *Human posture control, preparation gait to avoid slips and falls,* dissertation thesis, 2004;
[5] Pop C., *BIOMECHANICAL MODEL OF HUMAN BODY USING BONDGRAPHS. INVERSE DYNAMICS, SIMULATION AND CONTROL*, dissertation thesis, 2000;
[6] Operation manual of Kistler force plate