A 5-LINK MECHANICAL MODEL SIMULATING A FORWARD FALL PROCESS ON THE OUTSTRECHED ARMS

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Introduction

A forward fall is known as the most frequent type of fall and more than half of all falls among the elderly occur in a forward direction. As a result of forward fall on the outstretched hands, the upper extremity injuries belong to the most common ones. Recent decades brought numerous different models of the mentioned forward fall process (for instance, see papers [1-3]). In this study we propose a novel 5-link flat mechanical model of the human forward fall on the outstretched hands. Individual parts of the human body are modelled as a rigid body connected by the rotary spring-damper elements which correspond to the respective human joints. In addition, we take into consideration the human speed just before trip over an obstacle and starting the falling process which affects the final impact force acting on the upper extremity.

Methods

Equations of motion of the considered system are obtained by the Newton-Euler method implemented in Mathematica. In the first phase of a fall process (before impact to the ground) the system is forced kinematically in the joints corresponding to the knee, hip, shoulder and elbow human joints, and the system is reduced to the 1-DoF model (rotation around the ankle joint). In the second phase these joints are characterised by the spring-damper rotary elements, and then the system has 5-DoFs. Ground reaction force (GRF) is modelled by the classical impact law with spring and damper. The human body parameters are obtained based on the full 3D scanned human body model [4]. Initial angular configuration of all human body parts result from the position of the body just before tripping, while the initial angular velocities depend on the faller's speed just before this moment. The aforementioned joint angle time histories are estimated based on the kinematics of the falling process observed by using optoelectronic motion analysis system "Optitrack" (see Fig. 1).

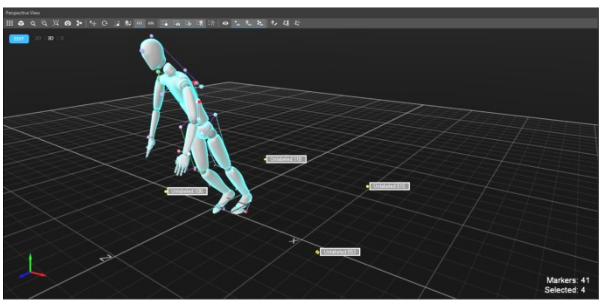

Figure 1: Forward fall in Optitrack system.

Results

Figure 1 presents the considered 5-link forward fall model simulated and visualised in Mathematica. The small colour dots represent human joints and/or the link tips, while the black ones represents centres of the gravity of the appropriate human body parts. The large black dot visible on the ground (yellow rectangle) denotes the ankle pivot point of the human body.

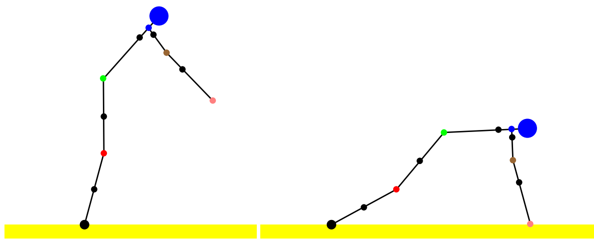

Figure 2: 5-link planar mechanical system of the human forward fall visualised in Mathematica before (on the left) and after (on the right) impact to the ground.

Discussion

The numerical simulations for the parameters obtained based on the scanning computer model of the human body and own experimental investigations fit well with numerical and experimental results presented in the literature, both from a qualitative and quantitative point of view. The proposed forward fall model allows to estimate the GRF in various scenarios of fall process. The further exact numerical analysis show that the essential influence on the obtained results have not only parameters describing the human body, but also the parameters modelling biomechanical properties between the palmar cartilages and the ground. The obtained GRFs can be useful for the further finite element (FE) transient state analysis of the numerical FE model of the human upper extremity.

References

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4. GrabCAD, 2016. Open CAD library. (https://grabcad.com/library)

Acknowledgements

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.