DEVELOPMENT AND VALIDATION OF A MORPHABLE ARTICULATED TOTAL BODY

Giulia Pascoletti (1), Elisabetta M. Zanetti (1)

1. Department of Engineering, University of Perugia, ITALY

Introduction

Articulated total body models, known as ATBs, are implemented in multibody codes, allowing for the acquisition of kinematic and dynamic information on the human body with minimal computational effort for subject-specific analyses, such as forensic biomechanics or for safety design. The most common ATB models are made up of articulated bodies having simple geometries [1] (such as spheres or ellipsoids), with the dimensions and inertial properties calculated through regression equations based on the subject's gender, height, and weight. More refined anthropomorphic models can be created using outer geometries obtained through laser scanning or other reverse engineering techniques and calculating inertial properties from a given density value. This article presents a novel method for developing an anthropomorphic ATB by segmenting a 3D parametric human geometry and morphing it based on up to 24 subject-specific measurements.

Methods

The anthropomorphic model's external geometry was obtained using specialized software [2], developed at Delft University of Technology. This software can generate the outer subject geometry for up to 24 anthropometric measurements, morphing a 'standard' geometry. Anatomical landmarks have been identified on this geometry and they were used to segment the whole body to identify 17 volumes corresponding to limbs, trunk sections, the head and the neck [3] (Figure 1).

The 17 volumes were articulated to one another through joints simulating the respective articulations. For each anatomical joint the ranges of motion, along with passive stiffness properties, were established for each degree of freedom, based on literature data.

The model has been validated against 5 cadaver tests performed at the laboratory of applied biomechanics of the Faculty of Medicine North, in France [4], aimed at replicating and investigating real-world pedestrian-car collisions.

Results and Discussion

Figure 2 reports the kinematic comparison between experimental results and numerical results for one of the tests: overall, there was a satisfactory qualitative agreement observed across all tests.

The qualitative comparison was followed by a quantitative one focused on time histories of velocities and displacements measured at the head center of mass; for example, Table 1 reports results obtained at the instant of time where the head impacts the ground: the absolute error could reach 0.8 m/s and the percentual error kept below 16%.

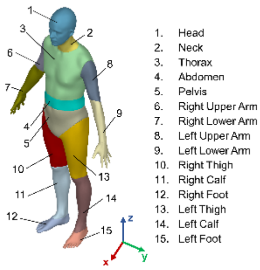

Figure 1: Morphable mesh of a male subject, segmented in 17 volumes.

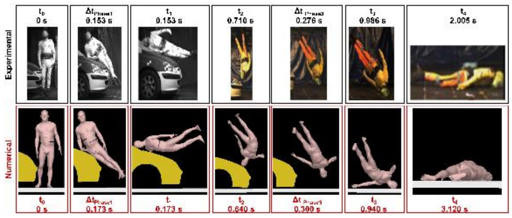

Figure 2: Kinematic comparison between experimental tests on cadavers (1st row) and numerical data (2nd row).

Test #	Experimental Head velocity [m/s]	Numerical Head velocity [m/s]	Absolute Error [m/s]	Percentual Error [%]
1	5.1	4.3	-0.8	-16
2	2.6	2.5	-0.1	-4
3	5.1	4.3	-0.8	-16
4	3.9	3.3	-0.6	-15
6	5.5	5.6	0.1	2

Table 1: Comparison of head velocity at time of contact to the ground.

The analysis confirmed the good predictive ability of the model; nonetheless, its accuracy could be improved adopting subject-specific stiffness behavior since it was evident that standard values actually do not exist. Future tests to study this aspect will be focused on living subjects, disturbed from their equilibrium condition.

References

1. Haug, E et al, Computational Models for the Human Body, Elsevier, Ansterdam (2004)
2. Huysmans, T et al, Tijdschrift voor Human Factors, 45 (2020)
3. Pascoletti, G et al., In C. Rizzi, et al., Design Tools and Methods in Industrial Engineering II – Proc. 2nd Int Conf on Design Tools and Methods in Industrial Engineering, ADM 2021, Spinger (2022)
4. Shang S et al, Kinematics and dynamics of pedestrian head ground contact: A cadaver study, Safety Sci, 127 (2020).

Acknowledgements

This work was supported by grants "Ricerca di base 2019' and "Ricerca di base 2020" from Università degli Studi di Perugia.