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TOWARDS PERSONALIZED VEHICLE SAFETY

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Abstract: *Human body models start to play an important role in safety system design. Comparing to dummies, virtual human models can be scaled to represent wide spectra of population. The paper describes the performance of virtual biomechanical human models as a support for design and optimization of not only passive and active safety systems used in various modes of transport. The accent is stressed on scaling where human subject of different mass, age and gender that can be created automatically. The difference in response for various subjects in impact scenario is shown.*
Keywords: *impact, human, virtual model, scaling, safety*

1. INTRODUCTION

The traffic accidents cause one of the highest numbers of severe injuries. The numbers of deaths or fatally injured citizens prove that the traffic accidents and their consequences are still a serious problem to be solved. The statistics show the decreasing number of accidents in the past years [9], but the decrease is still necessary to be speeded up regarding also the socioeconomic aspects of the problem [3]. A lot of effort is devoted to both passive and active safety systems development. The transportation standards usually define safety requirements by regulations (e.g. ECE-R94, 96/79/EC and ECE-R95, 96/27/EC in Europe) with specific dummies (e.g. Hybrid III 50% and Eurosid II). The dummies include sensors for monitoring accelerations, loads and other signals and each dummy is developed for a specific scenario but there are limitations of these dummies like only specific body size (5%, 50% and 95%) or calibration just for a specific test. Taking into account that the consequence of the traffic accident is highly influenced by the stature of the body, the virtual human body models start to play significant role because they can be scaled or even personalized towards a particular population or even particular person.

2. METHOD

Contemporary mathematical methods enable extensive analyses of technical problems by numerical approach. Many industry fields apply virtual prototyping towards new product development including virtual testing, where the whole process is modelled by computer software. The safety approach considers specific and biofidelic human body models to be developed and validated [1]. There are several approaches to be used in virtual human body modelling [5]. Whilst multi-body approach (MBS) performs in fast calculation times but with very limited application fields, detailed finite element models might predict very detailed level of behaviour including real fractures or ruptures occurring in the human body after external impact. That is why hybrid models benefiting of both approaches based on deformable segments linked together as by MBS is further used with the advantage of full articulation and very short calculation time.

2.1. Hybrid model

For the purposes of scaling, the authors are developing VIRTHUMAN [8], a special hybrid model, that benefits from both approaches combining them in an appropriate manner. The model is useful for dynamical simulations including interactions with safety systems. The basic model used benefits from the hybrid approach combining so called “*superelements*” linked to the MBS structure by nonlinear springs. Between the superelements, there are straps of elements without any response in order to keep continuous surface during articulation. The structure of the model is displayed in Figure 1.

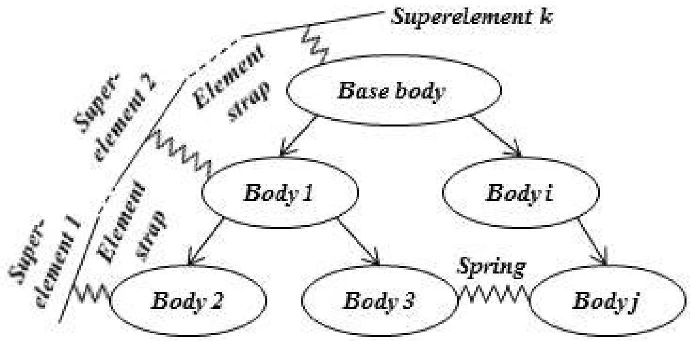

Figure 1: The hybrid approach

The reference geometry of the surfaces is chosen from the European database CAESAR in order to be close enough to Hybrid III 50 % and Eurosid II dummies as far as body dimensions are concerned **Error! Reference source not found.**. The MBS is defined as an open-tree structure that is required for scaling.

2.2. Scaling

The scaling algorithm is developed on the basic parameters of height, mass and age [6]. For the given age and gender, the height interval is proposed. For chosen height, the mass interval is proposed. Then, the model is scaled based a set of over 13.000 Czech sportsmen (males and females) measured by the Charles University in Prague (Faculty of Sciences, Department of Anthropology and Human Genetics) during the Czechoslovak Spartakiada in 1985 [3]. Flexibility scaling affects all joints in the human body by a multiplier based on the so-called "*flexindex*" [1].

2.3. Impact tests

To assess the scaled developed models, 2 impact (sled) tests were chosen [7]. The first one concerned 13 years old boy cadaver further referred as H7613DOT. The total height was 156 cm and the total mass was 50 kg that were the basic parameters for scaling. Other anthropometrical dimension after automatic scaling were also been checked in order to confirm the scaling process, see

Figure 2 and Table 1, where acceptable difference is approved.

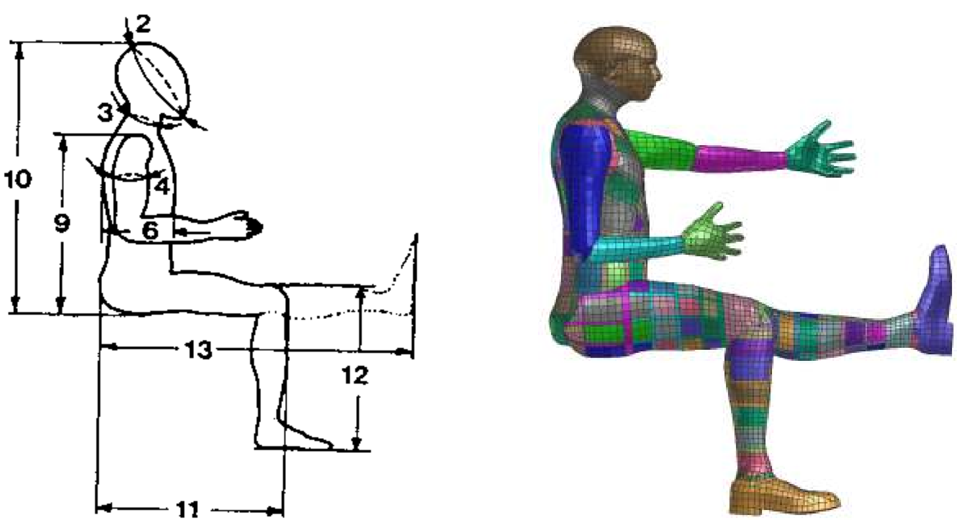

Figure 2: Human anthropometry (left) and scaled model to 13 years old boy (right)

Table 1: The anthropometric data of 13 year old boy (* denotes dimensions according to Figure 2)

Dimension	Cadaver	Scaled model	Difference [%]
Buttocks-shoulder (9*) [cm]	60	56	-7
Sitting height (10*) [cm]	81	78	-4
Pelvis-heel (13*) [cm]	82	94	15

The second test concerned 47 years old female cadaver further referred as H9311DOT. The total height was 169 cm and the total mass was 76 kg that were the basic parameters for scaling. Other anthropometrical dimension after automatic scaling were also been checked in order to confirm the scaling process, see

Figure 2 (left) and Table 2, where acceptable difference is approved.

Table 2: The anthropometric data of 47 year old female (* denotes dimensions according to Figure 2)

Dimension	Cadaver	Scaled model	Difference [%]
Buttocks-shoulder (9*) [cm]	145	141	-3
Sitting height (10*) [cm]	92	91	-1
Pelvis-heel (13*) [cm]	99	101	2

Both models were positioned into the sled test environment (see Figure 3) according to [7] and the same deceleration pulse as during the experiment was applied. The female test concerned also driver airbag.

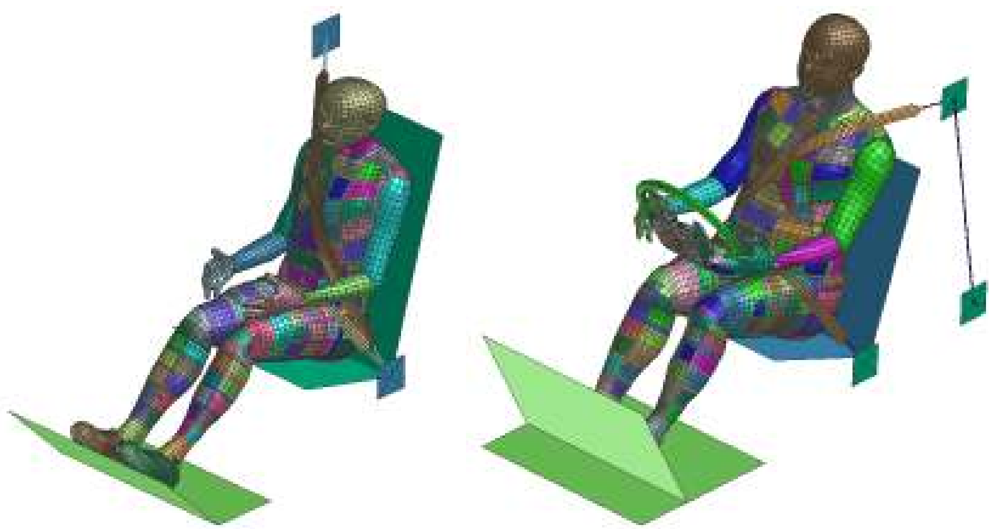

Figure 3: 13 years old boy (left) and 47 years old female (right) in sled test environment

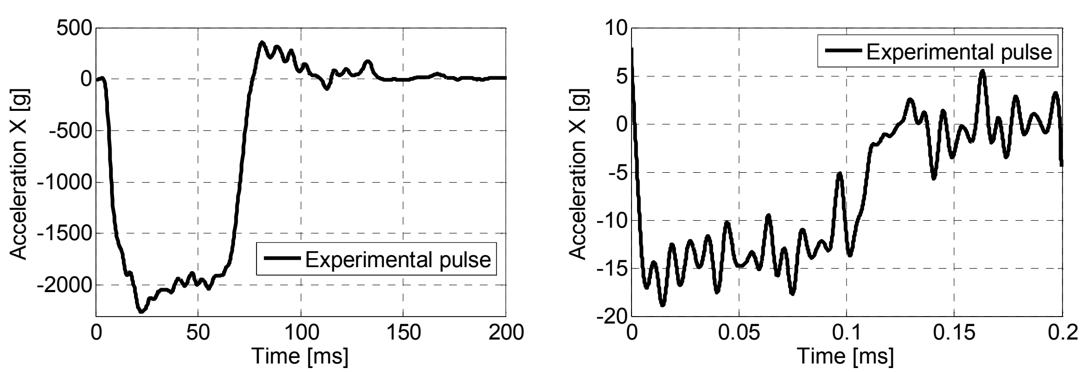

Figure 4: Deceleration pulses (left: 13 years old boy, right: 47 years old female)

3. RESULTS

Table 1 and Table 2 show that even based on few parameters, the scaling algorithm is able to develop subjects corresponding to the real anthropometry. Since the height and the mass are the scaling parameters, they are precisely the same for the scaled models. The 13 years old boy model fits to the 90th percentile, whilst the 47 years old female fits to the 92nd percentile within the anthropometrical data set [3].

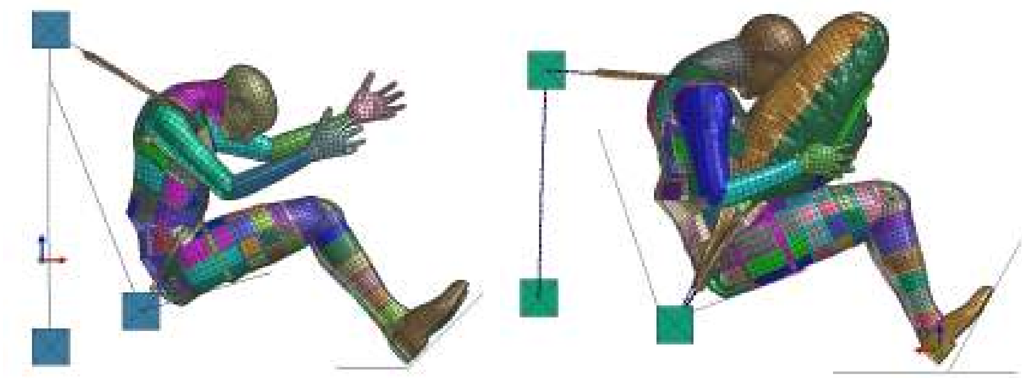

Figure 5: 13 years old boy, right: 47 years old female, both at 100 ms

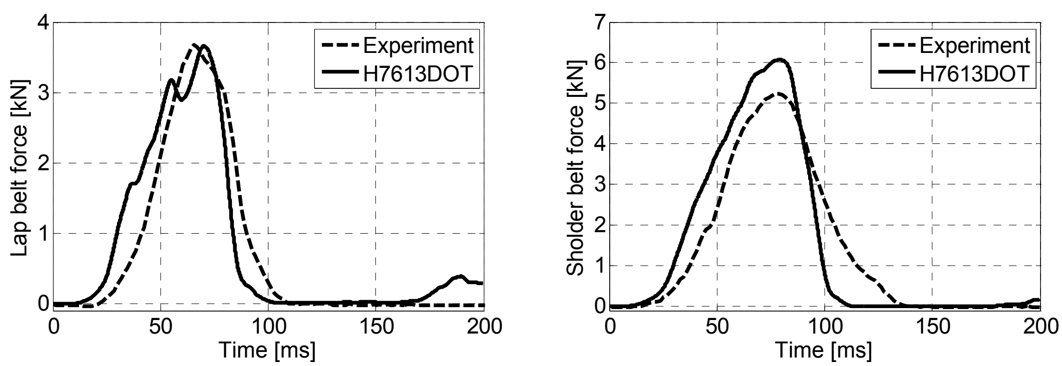

Figure 6: Lap belt (left) and shoulder belt (right) forces compared to experiment

The correct biofidelic performance of the models mentioned above was proven comparing the results to the available experimental data. Both the 13 years old boy model and cadaver were loaded by a deceleration pulse (see Figure 4 left) from the initial velocity equal to 41 km/h. The crucial entity influencing the whole response is the belt force. The time dependent belt forces are shown in Figure 6. Figure 7 shows the head acceleration in the local coordinate frame fixed to the head.

For the 13 years old boy model (H7613DOT), both the lap and shoulder belt forces correspond well to the experimental signal. The peak of the lap belt is reached around 70 ms and the peak force is around 3.5 kN (Figure 6 left). The peak of the shoulder belt force comes at around 75 ms and it is over 5 kN for the experiment and slightly over 6 kN for the simulation (Figure 6 right). The slight difference is acceptable.

The acceleration measured on head is also well corresponding including the head injury criterion that is very similar between the simulation and the experiment. The absolute value of peak of the frontal acceleration (Figure 7 left) is slightly over comparing to the experiment that is acceptable. The acceleration magnitude (Figure 7 right) corresponds well to the experiment except the experimental peak at 80 ms that is probably caused when the head hits the sternum. However, the head injury criterion (Figure 7 right) shows good correlation.

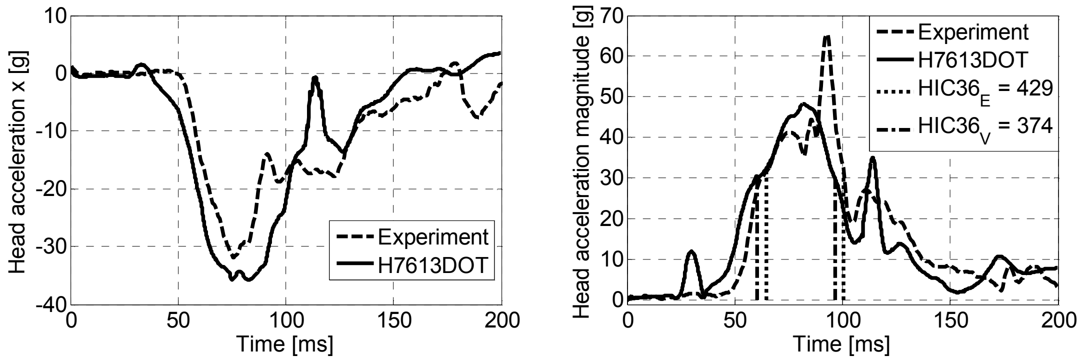

Figure 7: Head acceleration in the frontal direction (left) and head acceleration magnitude (right)

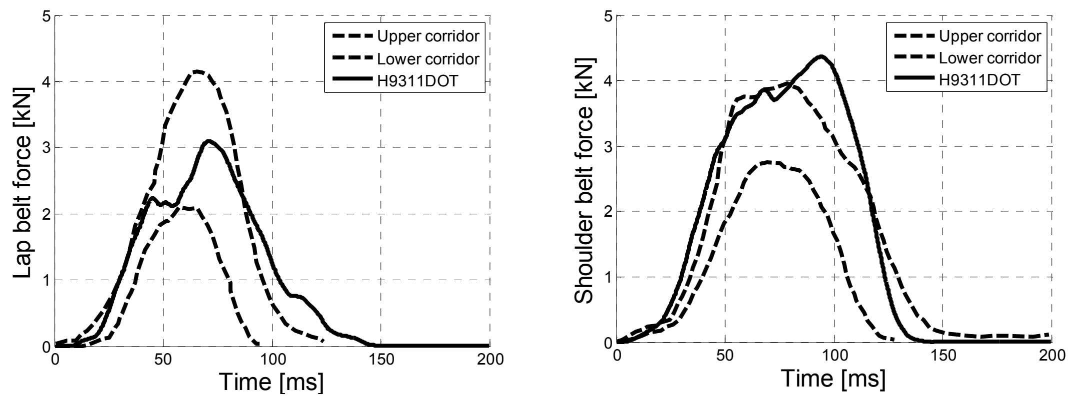

Figure 8: Lap belt (left) and shoulder belt (right) forces

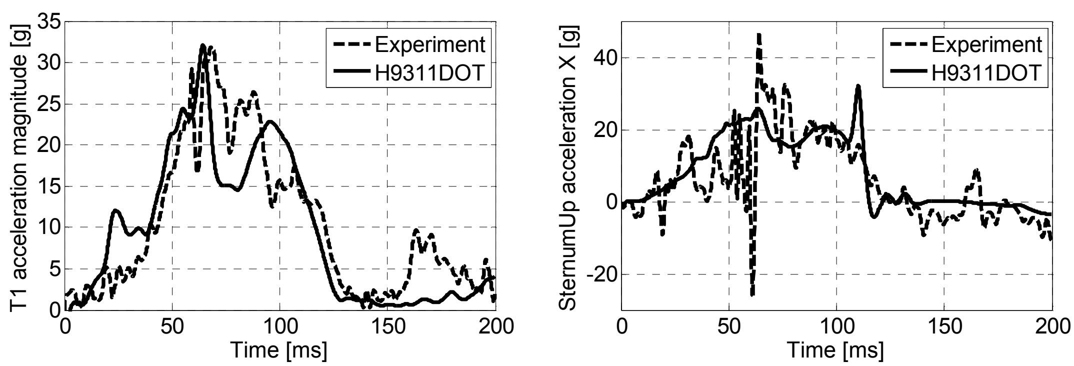

Figure 9: T1 acceleration magnitude (left) and upper sternum acceleration (right)

Both the 47 years old female model and cadaver were loaded by a deceleration pulse (see Figure 4 right) from the initial velocity equal to 49 km/h. Since the belt forces signal was not available, the initial response of the model was tuned in order the belt forces being in corridors from similar test. The tuning process means setting the parameters like friction coefficient and contact parameters.

For the 47 years old female model (H9311DOT), the lap belt peak force is 3 kN whilst the shoulder belt peak force is over 4 kN. As was mentioned above, the corridors do not correspond to this test; they are just use to tune the kinematics of the model.

The frontal direction acceleration measured on the vertebra T1 (Figure 9 left) fits quite perfectly to the experimental signal as well as the upper sternum acceleration in the frontal direction (Figure 9 left).

4. CONCLUSION

The paper summarized up-to-date knowledge in automatic developing virtual human models of various sizes. The present method developed by authors enabling anthropometrical scaling of multi-body based human models

is used. Hybrid approach based model performing in fast calculation with reasonable injury description was used and scaled to young boy and older women.
The correct response for the scaled models was shown to validate the scaling process. For 2 specific cadavers of different age, size and gender (13 years old boy and 47 years old female), the scaled models were developed and the sled test performance was tested and compared to experiment..
The paper proved that it is necessary to take into account particular body sizes in order to obtain a proper behavior of the body including injury assessment during the impact. The scaled models are useful and powerful tool for virtual assessment of human body behavior under loading regarding the wide spectra of population.

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