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ODBOR MODELOVÁNÍ HETEROGENNÍCH MATERIÁLŮ A BIOMECHANICKÝCH SYSTÉMŮ

AUTORIZOVANÝ SOFTWARE

PED2D

SOFTWARE FOR

2D CAR TO PEDESTRIAN FRONTAL IMPACT ANALYSIS

Autor: *Ing. Luděk Hynčík, Ph.D.*

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Odpovědný pracovník: *Ing. Luděk Hynčík, Ph.D.*

Vedoucí odboru: *doc. Dr. Ing. Eduard Rohan*

Ředitel centra: *doc. Dr. RNDr. Miroslav Holeček*

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Software description and user's manual (version 2009)

When a car hits a pedestrian, most of the action is done in a plane. From the dynamical analysis point of view, the analysis can be solved as 2D. The software is free to use or modify under the license conditions and it is developed in the MATLAB environment. The initial window is stated in Figure 1.

The software serves as a tool for fast 2D car to pedestrian impact analysis. The pedestrian model is composed using the Lagrange's equations with multipliers. The model consists of 11 rigid bodies defining the major human body segments; see Schneider et al. (1983). Robbins (1983) defines the segmentation of the human body that is accommodated in the model:

- Head segment
- Neck segment
- Thorax segment
- Abdomen segment
- Pelvis segment
- Thigh segment
- Calf segment
- Foot segment
- Arm segment
- Forearm segment
- Hand segment

Robbins also defines centres of gravity, masses, principal inertia axes and moments of inertia for all above-mentioned segments except the forearm and the hand. In the Robbins study, the forearm and the hand compose a single segment (body). Hence the total mass is divided between the two segments based on the relations defined by Karas et al. (1990). New positions of the centres of gravity as well as new moments of inertia were recomputed by static moments' equilibrium assuming that the principal axis direction remains unchanged.

Since the planar 2D modelling, all segments in the above list from thigh below include mass and other properties for both of the pair segments. All biomechanical data are taken from Robbins (1983). Three human anthropometries are accommodated:

- 5%-tile small female
- 50%-tile mid-sized male
- 95%-tile large male

The bodies are connected by rotational joints with non-linear response. There are the following joints implemented:

- Head/neck joint between the clivus bone and the vertebra C1 – The data described in Robbins (1983) concerns the response between the head and the thorax; hence the response was divided into 2 joints (head/neck and neck/thorax).
- Neck/thorax joint between the vertebra C7 and the vertebra T1 – The data described in Robbins (1983) concerns the response between the head and the thorax; hence the response was divided into 2 joints (head/neck and neck/thorax).

- Thorax/abdomen joint between the vertebra T12 and the vertebra L1 – The data described in Robbins (1983) concerns the response in the abdomen; hence the response was divided into 2 joints (thorax/abdomen and abdomen/pelvis).
- Abdomen/pelvis joint between the vertebra L5 and the sacrum bone – The data described in Robbins (1983) concerns the response in the abdomen; hence the response was divided into 2 joints (thorax/abdomen and abdomen/pelvis).
- Hip joint between the pelvis and the thigh
- Knee joint between the thigh and the calf
- Ankle joint between the calf and the foot
- Glen humeral joint between the thorax and the arm
- Elbow joint between the arm and the forearm
- Wrist joint between the forearm and the hand

The non-linear response for majority of joints is published by Robbins. The ankle and the wrist joints accommodate only the motion range with safety factor in the range limits.
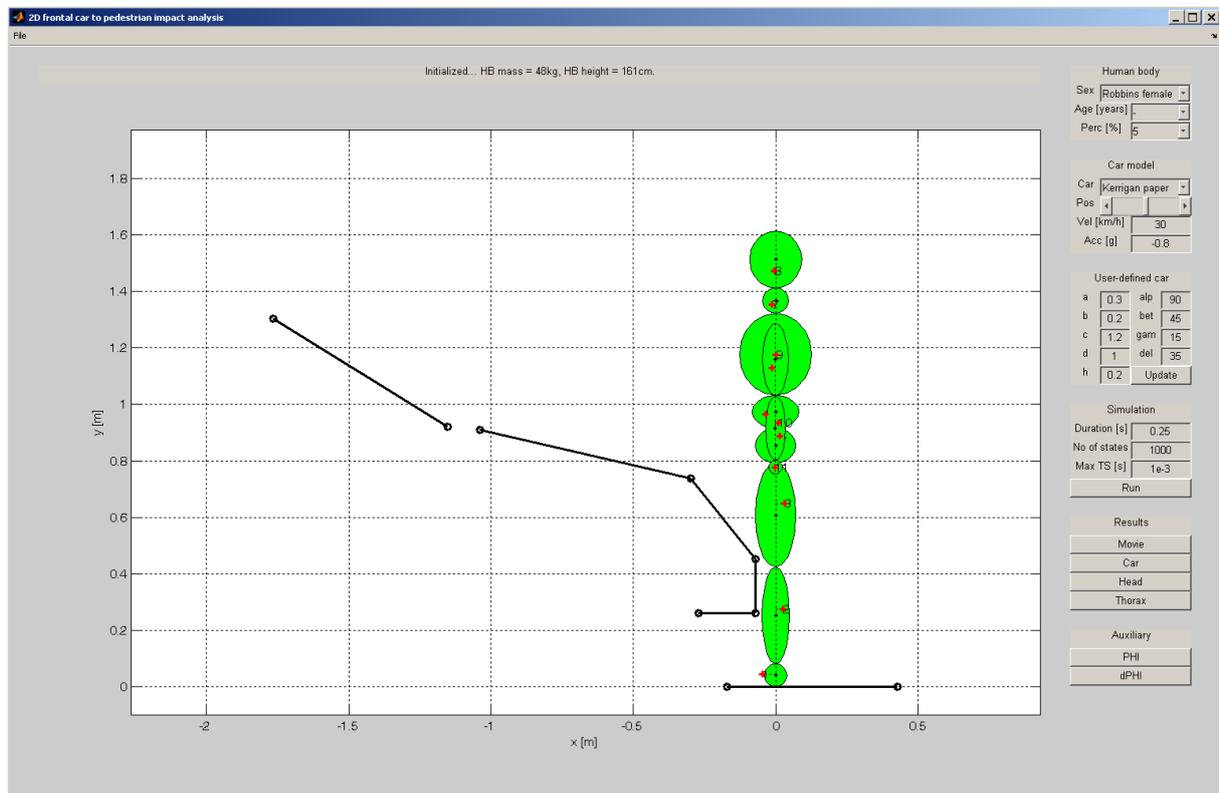

Figure 1: Initial window of the Ped2D software

The car model is multi-segment composed by lines. The basic implemented car is taken from Kerrigan (2005). The segments concern the bumper, the bonnet leading edge, the bonnet and the windscreen. However user can choose from other fictitious cars or can define the own one based on measures, see below.

Between the pedestrian and the car, there are contacts defined modelled explicitly by force-penetration dependence. The force-penetration dependence for particular car segments is taken from Simms (2006).

The use of the software is simple. It is started by the encrypted file *ped2D.p* from the MATLAB command line. In the initial window right column, there are five sections to be used. The first section shown in Figure 2 concerns the choice for human body anthropometry. The user can choose between the 5%-tile female model and the male models. In the case of male models, 50%-tile and 95%-tile body is implemented. The age pop-up menu is currently useless; it is just prepared for the update concerning age scaling.
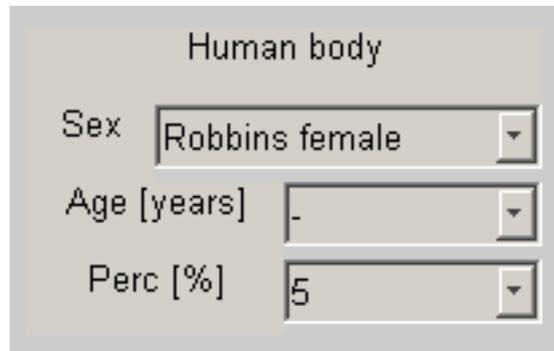
Figure 2: Human model choice

Figure 2 shows the car model choice. Three pre-defined cars and a user-defined car are implemented. Pre-defined cars concerns Kerrigan (2005) and fictitious geometries of a sedan and a light truck. The user can tune the mutual position between the pedestrian and the car by the slider. Car initial velocity and the acceleration shall be given otherwise pre-defined values 30 km/h and -0.8g respectively would be used.
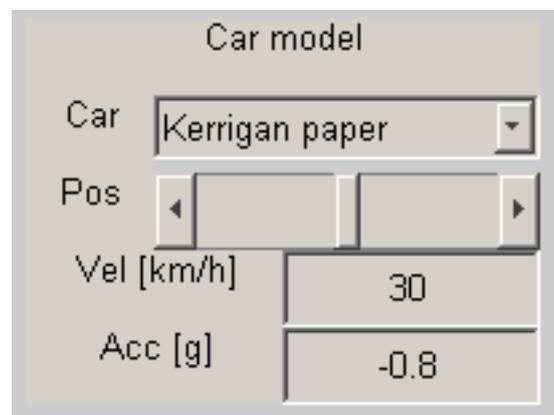
Figure 3: Car model choice

Figure 4 shows the parameters prepared for the user-defined car geometry. The "update" button updates the car model for the user-defined one. Figure 5 explains the length parameters a, b, c, d, h and the angles alp, bet, gam, del.
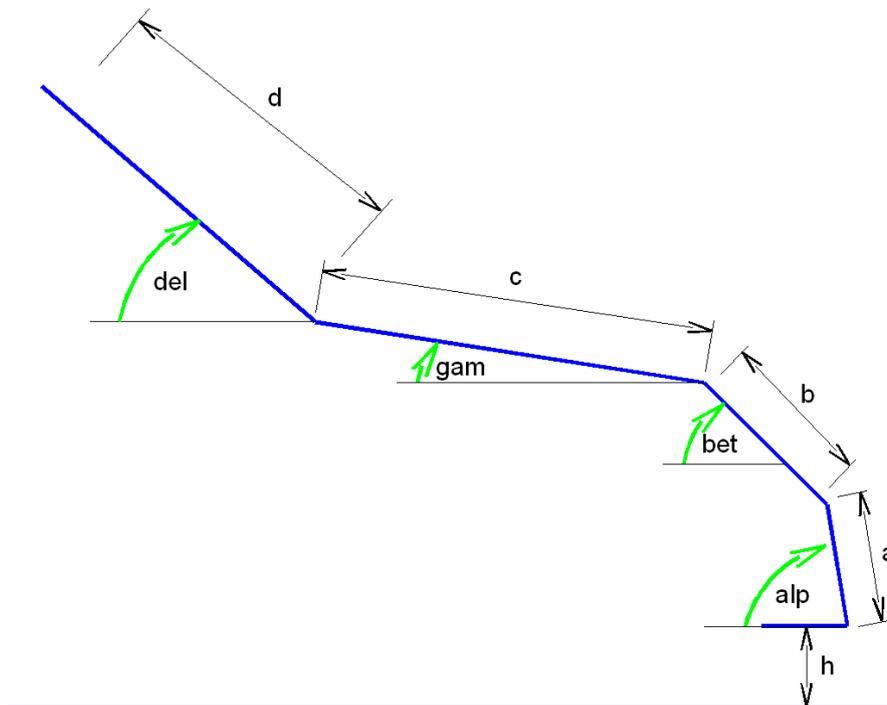
Figure 4: User-defined car model

Figure 5: User-define car model

Figure 6 shows the simulation setup. The user enters the impact duration to be simulated, number of states to be saved and maximum time step. The number of states defines how many points for results' curves will be saved. The maximum time-step pre-defined value should be acceptable for most simulations, however, in the case of bad convergence, the value is recommended to be decreased.
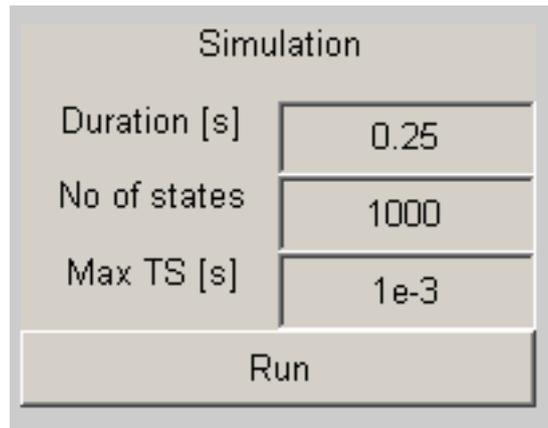
Figure 6: Simulation

Figure 7 shows buttons to create results' curves. The button "movie" plays the impact kinematics; the button "car" creates time-dependent curves of the car position and the car velocity; the button "head" creates time-dependent curves of the head position related to the car, the head velocity and the head acceleration; the button "thorax" creates time-dependent curves of the thorax position related to the car, the thorax velocity and the thorax acceleration.
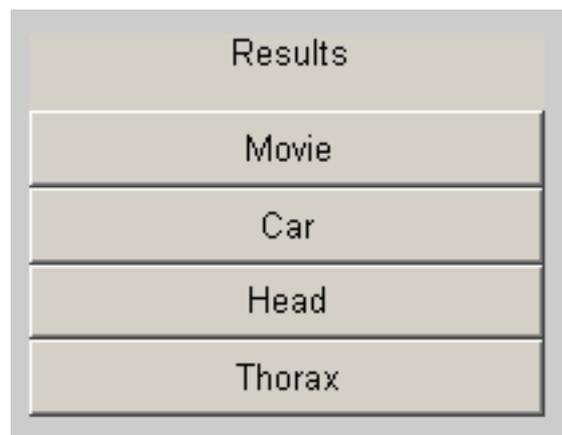
Figure 7: Results

Figure 8 enables to follow the constraints and their derivatives dependent on time. This numerical feature is useful for users interesting into the code improvement.
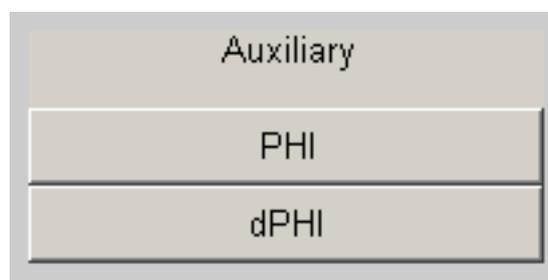
Figure 8: Auxiliary

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