Subject-Specific Pedestrian SAFER Human Body Models using a Rapid and Landmark-Free Mesh Morphing Method

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I. INTRODUCTION

Road traffic injuries are a leading public health concern worldwide. Almost half of all traffic-related deaths involve vulnerable road users [1], such as pedestrians and cyclists, and there are no indicators of any downward trends [2-3]. To establish targeted intervention strategies, investigations of traffic accident situations using virtual human surrogates are gaining ground among researchers and automotive industries. Recreating road collisions computationally using Finite Element (FE) human body models (HBMs) provides deep insight into human impact kinematics and injury mechanisms. One widely used HBM is the SAFER HBM [4-5], which represents a 50th percentile male occupant, supplied with an active muscle package that enables human postural control, and an extensively validated head model originally developed for brain injury research [6-7]. However, there is no currently available pedestrian version of the SAFER HBM V10. To address this limitation, we here present the development of two baseline upright, standing SAFER HBM: a 50th percentile male and female. In line with the increasing recognition of the need for HBMs to represent a wide range of human anthropometries, a personalisation framework is also developed and presented. The framework to rapidly obtain subject-specific pedestrian HBMs is based on a landmark-free, image-registration-based mesh morphing method.

II. METHODS

To acquire two baseline pedestrian HBMs (male and female), the SAFER occupant HBM V10 was positioned and morphed to have the outer body shape and inner skeleton geometry representative of an upright standing 50th percentile male and female. An overview of the approach is provided in Fig. 1.

First, the SAFER HBM was roughly positioned from seated position to standing position by straightening the initially bent legs and arms. The extremities were forced into position in a series of simulations using pulling cables. Second, a mesh morphing procedure [8] was followed to obtain the accurate 50th percentile human anthropometries. The morphing procedure is also used as a personalisation pipeline for the established baseline pedestrian HBMs.

Morphing framework

The image-registration-based morphing approach is based on the previously proposed framework for obtaining subject-specific head models by Li *et al*. [8]. In short, the morphing technique involves the generation of a displacement field that defines the transformation from a *template* geometry mapped onto a *target* geometry, subsequently applied to the nodal coordinates of the *template* HBM to morph it to the *target* HBM.

The initial *target* geometries are surface models of representative skeletons and body outer surfaces of the 50th percentile male and female. The target models were generated from available skinned vertex-based HBMs and skeletons developed from large datasets of body scans and processed medical images. The skinned vertex-based models, or so-called SMPL and SPMLX (see [9-10]), represent a wide range of body shapes in natural human poses and are generated by per-joint pose corrective blendshapes that depend on both body pose and BMI. The *template* geometry was simply the enclosed surface made up by the roughly positioned SAFER HBM (skeleton and outer skin surface).

The three-dimensional target/template surface geometries were then voxelised to binary images from .STL format. Using a diffeomorphic demons algorithm (non-linear image registration) in the publicly available software 3D Slicer, the template image was registered onto the target image, resulting in a resultant deformation field in written fileformat. When applied to the template HBM nodes, a new HBM with the assumed geometry (both outer body shape and skeleton) of the target model is generated.

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III. INITIAL FINDINGS

Two 50th percentile pedestrian SAFER HBM baseline models (male and female) were successfully generated. The Dice value, which is used to compare the agreement between the morphed binary images and their corresponding ground truth (scaled 0 to 1, where 1 is perfect image overlap), was calculated to be 0.95 and 0.82 for the male and female baseline HBM, respectively. The 95th percentile Hausdorff distance, defined as the maximum distance between any point on the template image and its nearest point on the target image, was 12.7 mm and 19.6 mm for the male and female baseline model, respectively. There was no decrease in the overall minimum Jacobian ratio (>0.12), and no new element intersections or part penetrations were introduced. Using the baseline models as template geometries, the morphing takes no longer than a minute to To assert the HBM biofidelity, three subject-specific HBMs were later simulated in pedestrian side-impacts using a generic vehicle buck for validation against PMHS experiments. The three simulated PMHS simulations showed fair correlation with published experiments with regard to trajectories, head contact times and kinematic time-histories of the head (e.g. average CORA rating of 0.70 for the head angular velocity, with a CORA rating of > 0.68 indicating a “good” correlation).

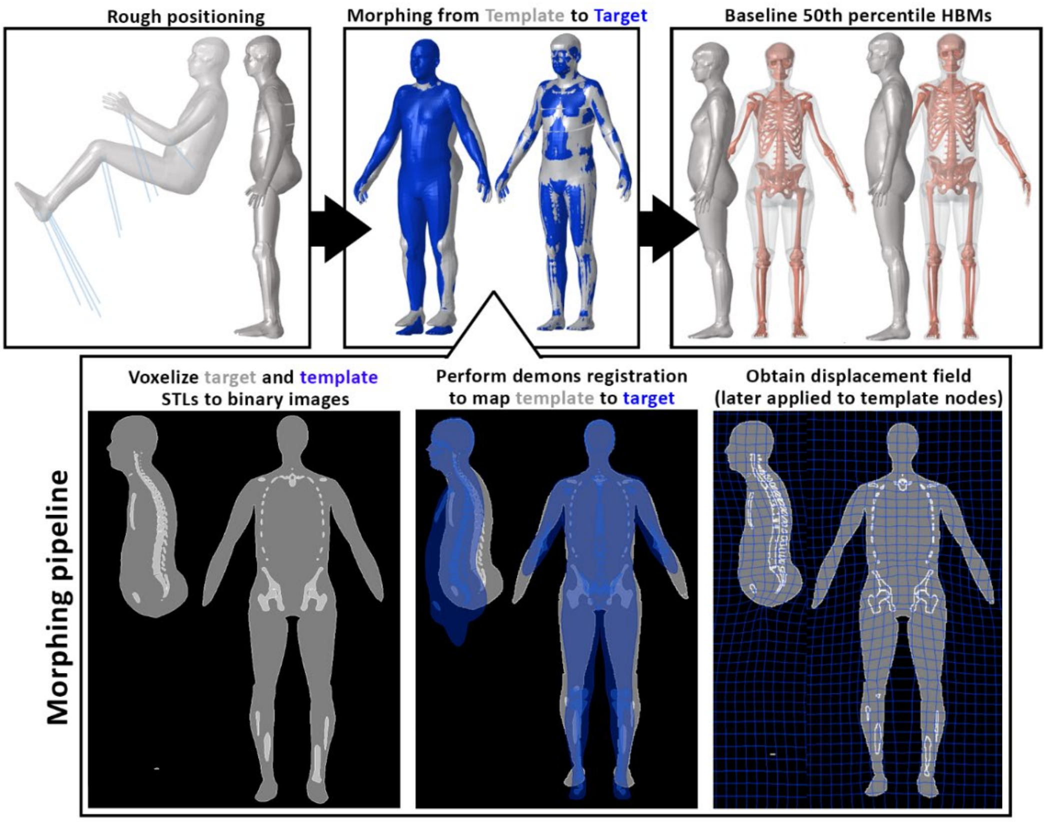

Fig. 1. Processing steps starting from seated, occupant SAFER HBM to standing, upright pedestrian SAFER HBM. Note that the morphing pipeline is also used for personalisation of the established baseline HBMs.

IV. DISCUSSION

In this study, state-of-the-art morphing techniques were utilised to develop baseline pedestrian SAFER HBMs. The presented personalisation framework has been shown to be a robust and rapid technique to generate subject-specific HBMs, considering both the morphology of the skeleton as well as the body shape/size. The baseline HBMs accompanied by the personalisation framework can be used for in-depth reconstructions of traffic accidents involving vulnerable road users, among many other applications.

V. REFERENCES

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