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Workshop: Open Source Human Body Model development Berlin - 17 October, 2018

Minutes of Meeting

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Minutes of Meeting

Work package 2, Milestone 2.1

Meeting attendees:
See list of participants (separate file)

Project details:	
Project start date: Duration: Project name:	01/06/2018 48 months VIRTUAL - open access virtual testing protocols for enhanced road user safety
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1 Context and objectives of the workshop

This workshop was organized to gather experts from industry, academia, and other organizations to discuss the current state of the art in development and use of computational human body model (HBM). The topics of discussion were selected by the partners in VIRTUAL WP2, and the output of the workshop will be used to refine the model development strategy envisioned in VIRTUAL.

Furthermore, speakers were invited to share their view, knowledge and experience on topics relevant to the overall objective of VIRTUAL. Each speaker presented a few slides to trigger questions and discussion with the attendees and project partners.

2 Welcome and introduction

Mats Svensson (WP2 leader): General welcome to participants

- Motivation for workshop
- General presentation of **VIRTUAL**, see slides
- It was highlighted that VIRTUAL aims to establish a dialogue with other HBM related initiatives to ensure win-win collaborations

Johan Iraeus: Introduction to questions which should be addressed in this workshop (see slides)

- Possible approach to model refinement: Existing model → refine model and add injury detection systems → additional validations → morphing → re-position for test cases
- Or, different approach: Create "core model" → optimized morphing procedure → validation of morphed versions
- **Challenges:**
  - Morphing/scaling
  - Modularity
  - Simple vs. complex models
  - Validation of morphed? Modified? HBMs
  - Expected future use
  - Translation to other codes
  - Open Source (OS) issues/maintenance

Comments from the audience:

- Kinematic validation of the model might not be sufficient for use in product development as injury risk values are what will guide design decisions. What injury criteria will be used as result from HBM simulations?
- What is the age of the VIVA model today? What is the age of the individual that was used to derive the geometry and what age do the material parameters correspond to? There are several anatomical variations resulting from aging that perhaps need to be accounted for. Johan commented that the variation due to aging can be less than the variations observed within the human population
- Will you aim at simulating the full pre-crash sequence for pedestrians and bicyclists? Will the models include active muscles? Focus in project right now is to include active muscles to assess their contribution to the response of the human body during the crash-phase and to the control of the posture during the pre-crash phase.

3 Invited speakers

Philippe Petit: Piper experience on scaling

- About PIPER: OS project, that provides a set of tools for positioning/personalisation that is independent of the FE solver used to run the simulation (should it be LS-DYNA, VPS, Radioss,…).
- The PIPER software uses a set of meta-data to manipulate any HBM, such as landmarks of certain bones etc. based on databases of anatomical landmarks.
- About developing a **core model:** there should be an **initial purpose** for the development of such a model. There is a trade-off between the ability to modify the model by morphing it and the level of details in the model. One needs to make the right choices to get a model that meets the desired requirements.
- Suggestion: "Go deep into PIPER" → Invitation to fill the open gaps and to contribute. Scripting in PIPER can be very useful for the core model approach.
- Request to VIRTUAL members to document, whenever something useful is identified or something is changed and to share experience with other PIPER users. Documentation of PIPER functions is currently incomplete.
- Validation of **morphable** core model: no experience with that, but it is probably difficult. A qualitative comparison of the GHBMC model to PMHS tests was presented by Philippe Beillas at IRCOBI this year (2018). However, it is not clear how morphing affects validation.

Duane Cronin: Modularity

- **Evolution of models:** Level of detail has mostly been given by what was computationally feasible and therefore significantly increased throughout the last years.
- Prediction of injury risk. It can be done based on different scales: Global (vehicle acceleration), Global biological response (multi-body model, dummy like criteria), local biological response (Injury risk at the tissue level).
- Modularity in the form of **substructuring** has been around in FE modelling since the 1970s.
- Another type of modularity: multi-scale modelling, using the results of a simulation of coarser model as boundary conditions for a more detailed model. Example: Model of blast exposure, simple whole body kinematics, more detailed head.
- Simplified components can work as long as St. Venant's criterion is met and the kinematics is correct. Example: side-impact with detailed thorax and simplified arms and head.
- A modular type of model "can work, if you ask the right questions."
- **Critical points:**
    - Simplified models have to be validated against full-complexity model
    - Transitions and boundaries where simplified and more complex structures are combined
    - Tissue level response is very sensitive to small changes in geometry

- **Questions/Comments from the audience:**
    - So many different models for different things – from an industrial perspective, it is sometimes better to only run **one** complex model of entire body. When you have to run multiple simulations with modular models instead of one simulation with a complex model, efficiency is limited and it is not beneficial from practical point of view, as not only one number is needed from one simulation.

- Modularity is not limited to the spatial domain, but also in the temporal domain which could further benefit from a modular approach. We also have to handle the age of the occupants which affects not only the anatomy but also material properties.
- It is hard to define a “normal” response to validate these models with. Natural variations in human population should not be ignored, but be taken into account (example of gait styles was given). Variability in terms of geometry and material properties is increasing with age. The validation with PHMS tests became more difficult over time because of increasing average age of body donors.
- Aging is not only a morphing exercise, tissue level changes make it very challenging
- The purpose and limitations of the model have to be clearly defined. We are currently often facing the challenge that we try to answer bigger questions than we had in mind when developing today’s state-of-the art models.
- It is recommended to start with a detailed model as core model and then simplify specific body regions depending on the intended application
- Suggestion to use a “population” of HBMs to deal with inter-individual variability. That would be easier to do with simplified/modular models.
- One way forward for more detailed validation could be the use of open source models, because then more efforts can be put into validation and development of models to capture more detailed responses.
- How much computational time does sub structuring save? → Answers from “5-10%” up to “8 to 10 times.” But: Trade-off between time gain in running the models and time invested for developing/validating reliable simplified models.
- Benefit of modularity and simplified models is highly dependent on the characteristic time of the event of interest. For instance, running pre-crash and in-crash simulations can take months with a detailed model.
- Assessment with tissue based criteria can be challenging as pre-stresses from repositioning need to be considered.

Steffen Peldschus / Therese Fuchs: Harmonised Objective Validation

- Working on a set of **validation load cases** made available on web page of THUMS user community (TUC) in validation repository.
- A limitation in their work is that they cannot publish any details of the HBM, as all details of THUMS are IP protected. Therefore very detailed documentation is needed to specify the setup of the validation tests in a generic way. There will be an advantage in using Open Source models for the harmonisation of validation activities, as it will be possible to include the HBM in the setup files.
- Already available load cases:
  - Rib bending tests, lateral loading (Del Pozo et al. 2011)
  - Pedestrian load case with beta model of the SAE pedestrian impact buck (PMHS tests published by Forman et al., 2015)
- Load cases in preparation:
  - Load cases from SENIORS project. Tests were done with both volunteers and PMHS. TUC processes the data and generates FE environment for simulation of the tests. Subsystem (femur, intervertebral disc tests) setups on being prepared
  - Frontal sled tests (Gold standard) from Shaw et al. (2009)
  - Femur tests published by Forman at el. (2012)
  - Disk compression (lumbar spine) – validation presented at IRCOBI this year by Draper et al
- TUC is open for collaboration with other initiatives

- **Questions/comments from the audience:**

- European Commission funding rule: data produced by funded projects must be made available, even if it has not been exploited within the project. Therefore, it is likely that there is more "hidden" data around which could be published in a similar fashion. During PIPER project, it was sometimes difficult to obtain this kind of data from other research groups (in spite of EC requirements)
- OS HBMs should be beneficial, as the HBM as a whole could serve as "information container" (e.g. for CT data on subject size or initial posture of the PMHS)

John Combest: Complex vs. Simple HBMs, GHBMC experience

- John Combest works at Nissan and is the chairman of the GHBMC.
- It is good to see discussions and groups promoting use cases for HBMs.
- GHBMC used **different approach**: detailed → simple. They started with detailed models of single individuals, representative of the average morphology. At a later stage, simplified models were derived from complex models.
- Concerning the issue of "**future use:"** Number one goal for GHBMC is to provide a model **for a specific purpose**: Focus is on accurate modelling of crash induced injuries. GHBMC is very focused (no models of bicyclist, motorcyclists, modelling of sport injuries,.).
- Open Source approach: That is a novelty from the industrial perspective. A challenge for the open source models if their long-term maintenance.
- Validation: Sometimes, experiments are hard to reproduce due to missing detailed information about experimental setup. GHBMC used the validation load cases that were reproducible.
- Regarding to modularity, it is challenging to decide where to section the model. Perhaps the spine is more of a functional unit than the thorax for instance.
- What applications the model will be used for is difficult to anticipate – novel developments right now are relaxed reclined positions.
- Industry is also interested in ATD-like HBMs.
- "Morphing for age is more challenging than morphing for size."
- "All models are wrong – just some are useful."
- It is essential to decide how the models should be used.

Hyung Yun Choi: Multiple Codes and Translation

- Quick survey of the solver use in the audience: 1. LS-DYNA (approx. ~70%), 2. VPS (~20%), and 3. Radioss and 3. Abaqus (~5% or so each, tie).
- **Model conversion process:** LS-DYNA input model→converted to VPS or RADIOSS → validation→ release.
- Validation: a number of **defined load cases** at multiple length scales (components, upper body, full body). Translated models are correlated with PMHS data. This can be problematic when the translated models perform better than the original ones, which can lead to inconsistencies among the models in different codes.
- About **core model:** should use features which exist in all codes and are therefore easy to translate.
- Upcoming developments for the GHBMC: an active model which will be validated w.r.t. data from Beeman et al.

- **Questions/comments from the audience:**
  - There is a paper by Therese Fuchs on model translation

- Input from translation point of view to GHBMC is to only use features which work across multiple FE solvers. There are a lot of features in LS-DYNA which do not exist in VPS or Radioss
- Benchmark for element definitions, plastic strain definitions, contact definitions in different FE solvers would be useful

4 Discussion and questions

Question by P. Petit: Why are we talking so much about models and not about test protocols?
Mats Svensson's answer: In VIRTUAL, a few uses cases will be targeted for virtual testing. One of the use cases is rear end collision with a focus on whiplash injuries. The VIVA model, which is the starting point for the VIRTUAL models, is developed particularly for this purpose. Criteria we will look at in the VIVA model is facet ligament strain and spinal fluid pressure transients. When it comes to whiplash protection systems, we will then use the models to extend the test results. Parameters to change are for instance the sex and size of the occupant. It is possible that this will show a need for adaptivity in protective systems in vehicles.

Mats Svensson: Quick summary of the discussion so far. Are there other comments or questions?

Comments from the audience:
Answer from VIRTUAL partners (if any) are shown in Italic.

- For universities, Open Source models are very helpful. However, using coherent terminology would be very helpful. Therefore, common name spaces, standards for development procedures etc. should be specified. PIPER is probably a good standard for that.
- Which unit system is being used, and how can different unit systems be translated?
  *A: mm ms kg is used in VIVA. *INCLUDE_TRANSFORM should work for most situations.*
  The effect of unit translation on strain rate parameters should be checked. Include files in different unit systems might be useful.
- Morphing is challenging and risks producing bad outputs. Going from seated occupant to standing model will most likely require manual remeshing.
- Is there a demonstrator for simplified/modular models?
  A: For the VIVA model currently most body regions are simplified, as focus was put on the neck.
- For pre-crash simulation it would be more interesting to have a simplified model with active muscle control, as detailed models need much computational time for this long time frames.
- Are you using PIPER or implicit calculations for positioning?
  A: We intend to use PIPER for positioning. Positioning can be done there either geometrically or through a script so that positioning is performed during pre-simulations.
- An interesting offer would be seminars and /or tutorials. That might help with long-term sustainability. *A: Dynamore will take care of such activities and is an important partner for VIRTUAL to ensure sustainability.*
- Which injury scale is used, and how is injury linked to strain?
  A: Defining proper criteria is challenging for some body parts. We aim to have Injury Detection Systems implemented in the HBMs that are able to predict injury of specific AIS severity.