Towards an automated workflow for generating finite element models of the knee

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Background

Computational models of the knee are routinely used to understand the patient specific form-function relationships in healthy and diseased knees. Simulation-based explorations have become increasingly popular (Figure 1). But, the credibility and reproducibility of these simulation results are questionable[1]. Therefore, it is important to identify and minimize subjective components in modelling and simulation workflows (Figure 2), such as sources of human error. Manual segmentation of 3D images is not only time-consuming, but also a large source of human error.

Here we present an automatic workflow (Figure 3) for generating patient specific finite element (FE) models of the knee from MRI.

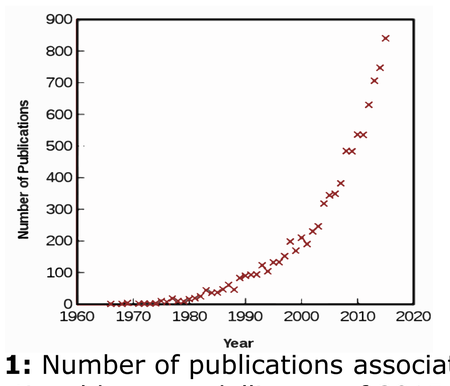

Figure 1: Number of publications associated with computational knee modelling as of 2015.

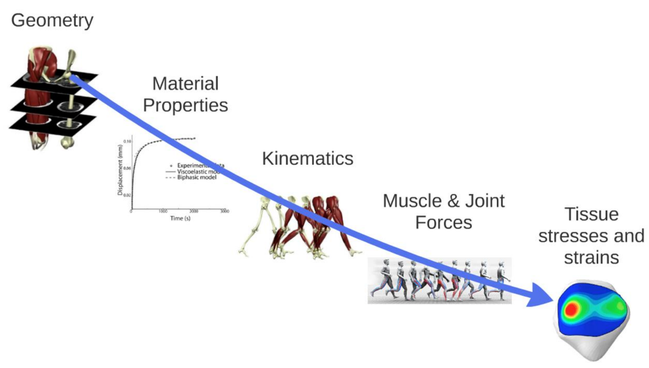

Figure 2: Generalised workflow for model generation.

Method

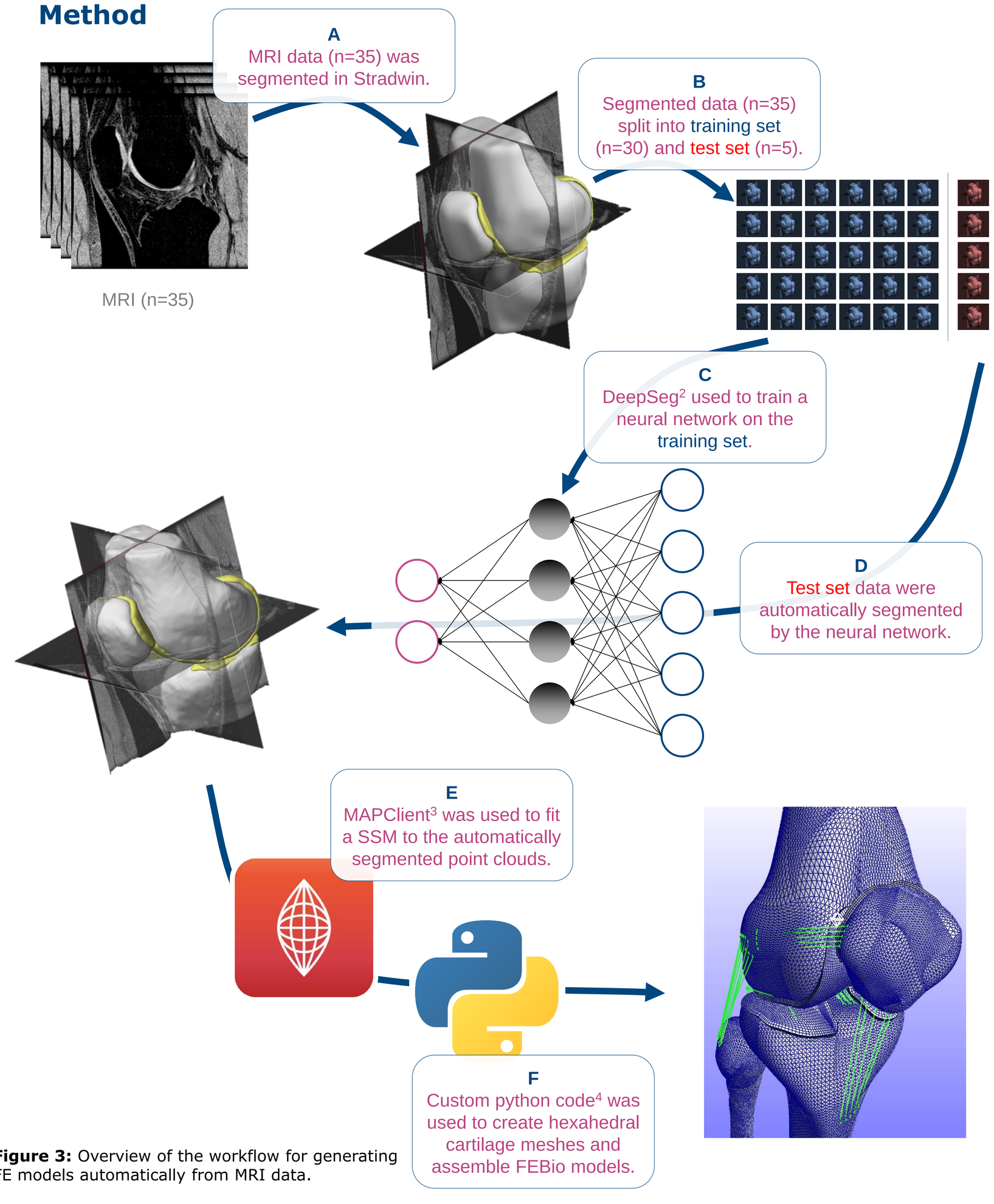

Figure 3: Overview of the workflow for generating FE models automatically from MRI data.

Results

We compared the error between FE models generated from automatically segmented and manually segmented data. The mean error in the FE models generated by automatically segmented data was 0.83±0.91 mm. DeepSeg DICE scores were good despite a small training set of only 30 datasets. Mean total time taken to generate FE models from unsegmented MRI data was 19m 42s, compared with over 6 hours manually (Table 1).

Table 1: Mean errors between FE meshes produced from automatically and segmented data, segmentation DICE scores and approximate time taken to generate the FE knee model.

	Average
FE mesh mean error ± std (mm)	0.83 ± 0.91
DeepSeg mean DICE score bone	0.945
DeepSeg mean DICE score cartilage	0.753
DeepSeg segmentation time	02m 42s
FE mesh generation time	17m 00s

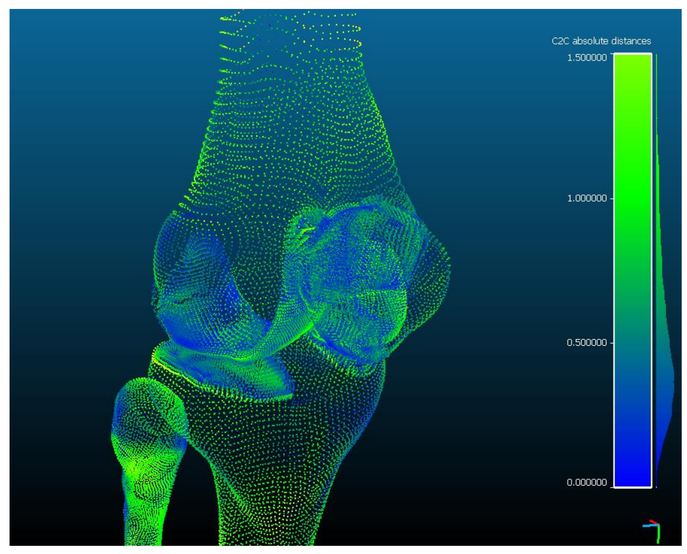

Figure 4: Error distribution between FE models generated from automatic and manual segmentation.

Summary

The results show promise for a fully automatic tool that improves both the reproducibility and speed of musculoskeletal modelling workflows.

In the future we plan to extend the training set and use continuum representations for ligaments to improve the models generated by the workflow.

References

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3. Zhang J et al. (2014). *Biomed Sim.* **8789**, 182-192.
4. Kazemi M. (2018). *The University of Auckland (Doctoral Thesis)*.

Acknowledgements

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