Developing an Automated Method for Parametric Human Modeling

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Introduction

Parametric Human Modeling

- Human size and shape have significant effects on human impact responses and injury risks in crashes, but conventional human models only represent occupants in a few sizes, namely midsize male, small female and large male, which has resulted in safety equity issues [2].
- Parametric human modeling can account for the morphological variations in both skeleton and external body shape among the population [1], and can rapidly generate a large set of human models representing a diverse population to assess safety designs and improve safety equity in motor-vehicle crashes [2].

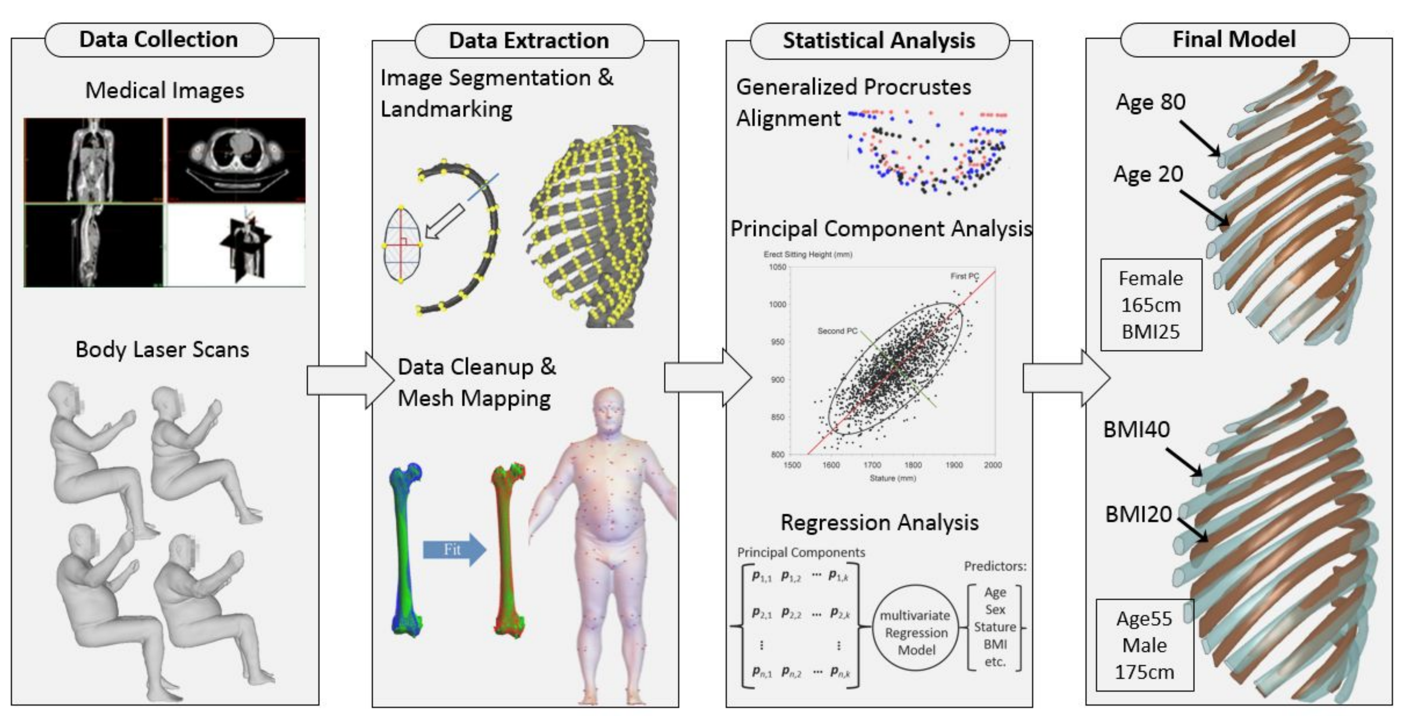

Figure 1: Current approach to develop parametric human skeleton model

Limitations of Current Methods

- Template mesh mapping requires manual landmarking on each sampled subject, which is very time consuming.
- Often associate with large regional errors that were not covered by the landmarks.

Objectives

Develop an automated mesh morphing method to map a template mesh onto the subject geometry

- Create a geometrically more accurate mesh of each subject while keeping the baseline mesh quality largely intact.
- Include a self-correction mechanism for areas with large geometric errors or bad mesh quality in the morphed model.
- Automate the landmarking process to decrease the number of manually placed landmarks.

Methods

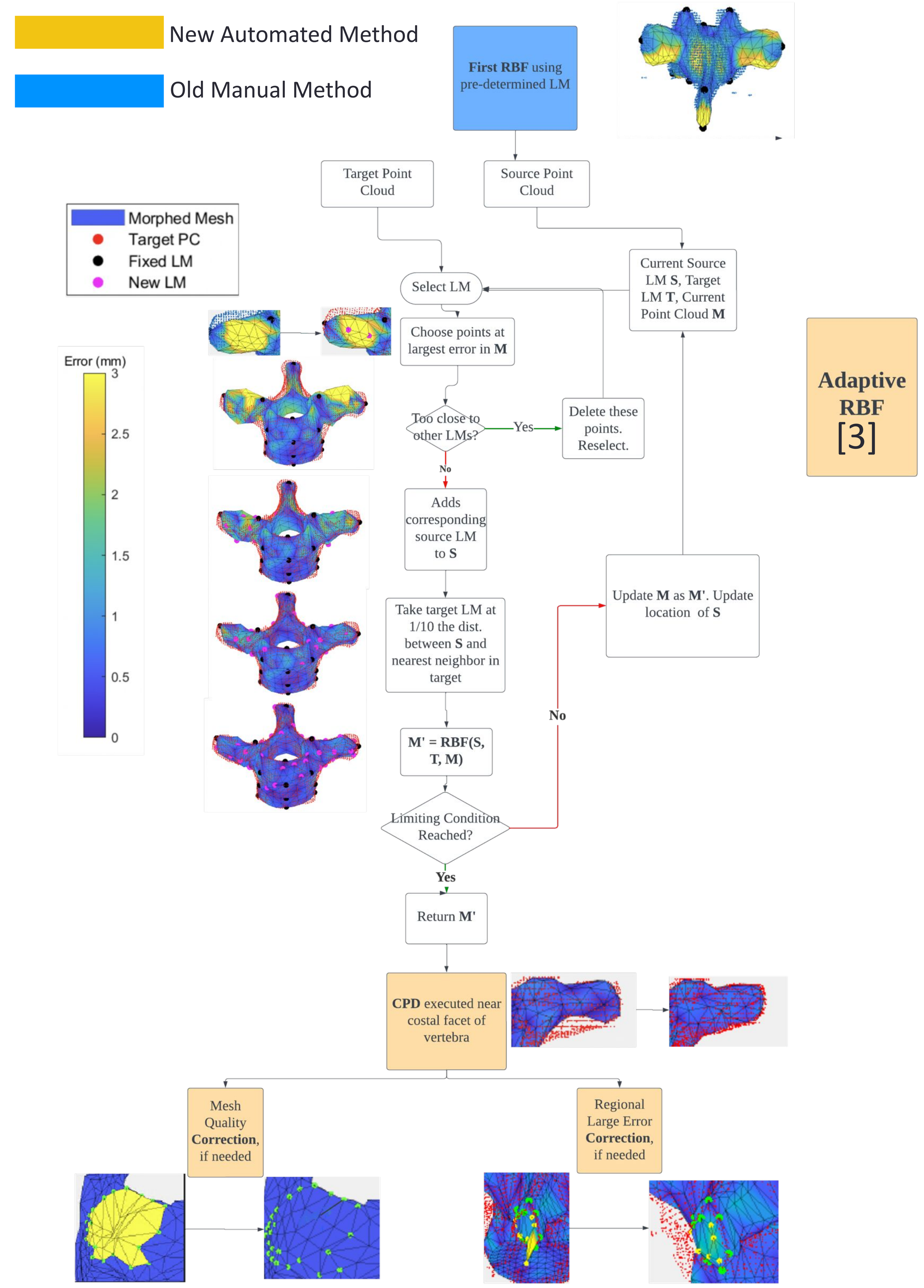

Figure 2: Methodology Flowchart

- Previous mesh morphing (in blue) uses RBF on 19 manually marked landmarks. Employed at the start.
- Adaptive RBF is an iterative process. It places landmarks near points with the largest errors.
- Adaptive RBF places target landmarks at 1/10 the distance between S-LM and closet neighbor. Location changes every iteration.
- Coherent Point Drift (CPD) accounts for regional inaccuracies in the costal facet regions. No landmarks are needed.

Results

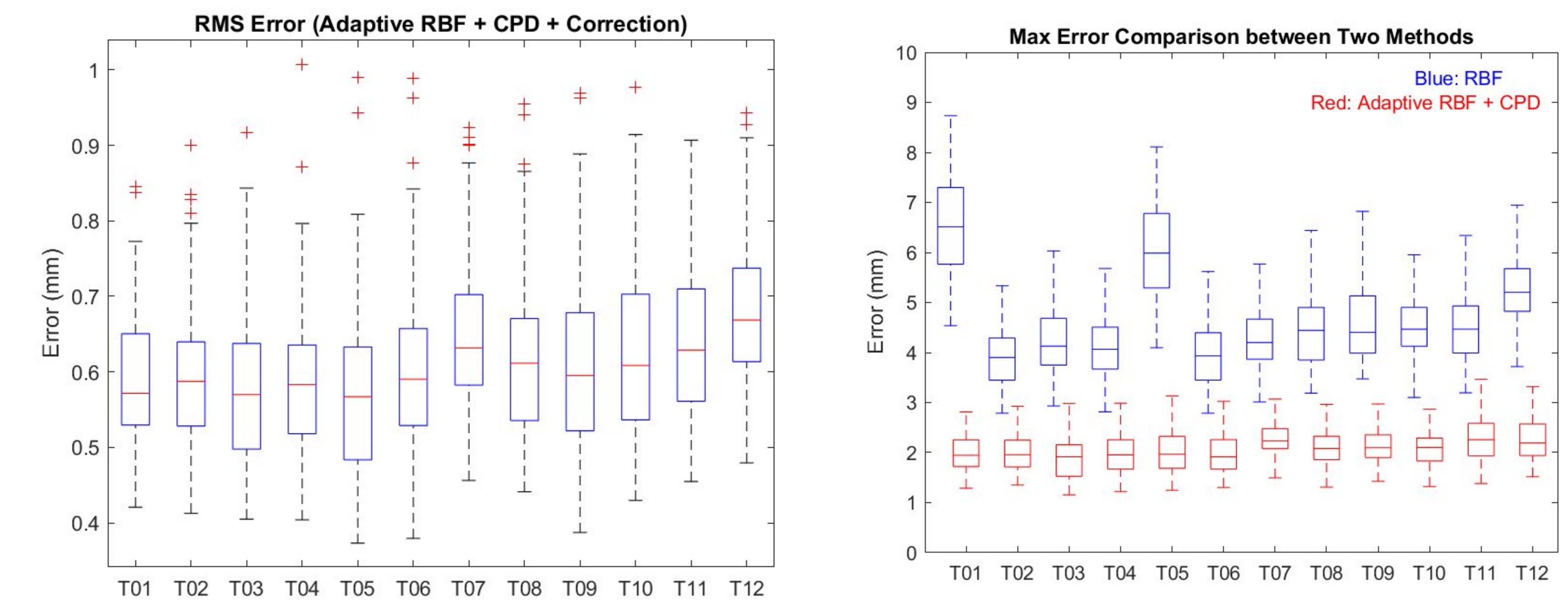

Figure 4.1 & Figure 4.2: RMS and Max Error Comparison Boxplot with Adaptive RBF

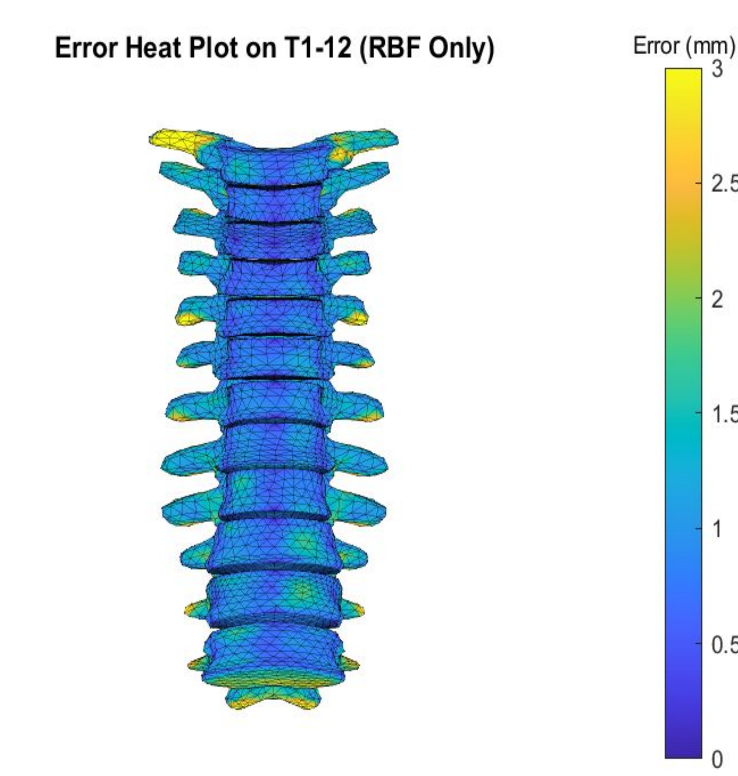

Figure 4.3: Error Heat Plot for RBF

There are still visible regional inaccuracies, especially around the costal facet area.

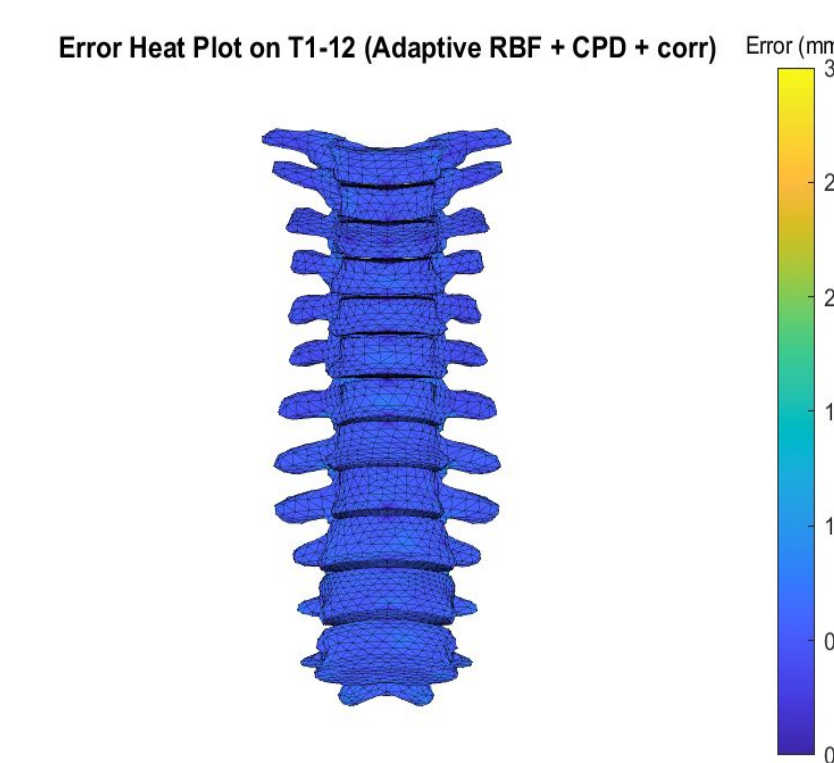

Figure 4.4: Error Heat Plot for New Method

In contrast, the regional inaccuracies are not visible.

Conclusions and Future Work

- The newly developed adaptive mesh morphing method has increased the geometric accuracy of the mesh for all sampled subject.
- A re-morphing method was integrated to correct the rare large geometric errors or low-quality mesh after the initial adaptive mesh morphing.
- The adaptive mesh morphing method can automate the landmark placement process smoothly.
- Future work will focus on reducing the manual landmarks from 19 per vertebra to 4 per vertebra.

References

[1] A. Wei, J. Wang, J. Liu, M. L. H. Jones, and J. Hu, *A parametric head geometry model accounting for variation among adolescent and young adult populations*, Apr. 2022.

[2] J. Hu, "Parametric Human Modeling," in *Basic finite element method as applied to injury biomechanics*, Y. King-Hay, Ed. London: Academic Press, 2018, pp. 417–445 .

[3] Ju Zhang, David Ackland & Justin Fernandez (2018) Point-cloud registration using adaptive radial basis functions, Computer Methods in Biomechanics and Biomedical Engineering, 21:7, 498-502