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

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Computational models are changing the world

Nakamura et al. (2017)

Monk et al., (2019)

Li et al., (1999)

Erdemir et al., (2017)
Reproducibility of knee models is questionable

Baldwin et al. (2009)

Blankevoort et al. (1991)

Weiss et al. (1996)

\[ f = \begin{cases} 
\frac{1}{4} k \epsilon^2 / \epsilon_b, & 0 \leq \epsilon \leq \epsilon_b, \\
k (\epsilon - \epsilon_b), & \epsilon > 2 \epsilon_b, \\
0, & \epsilon < 0,
\end{cases} \]

Li et al., (1999)

Weiss et al. (1996)

\[ W = c_1 (I_1 - 3) + c_2 (I_2 - 3) - 2 (c_1 + 2c_2) \ln J + F(\lambda) + U(J) \]
Neural networks can be trained to segment medical imaging data automatically

n=35

1Formus Labs, Auckland
Overview of the process: MRI to FE model

Test set MRI

Manual segmentations
Neural network needs more training data
FE meshes generated are comparable between manual and automatic segmentations
The workflow is very promising in producing reproducible models

<table>
<thead>
<tr>
<th></th>
<th>Test case 1</th>
<th>Test case 2</th>
<th>Test case 3</th>
<th>Test case 4</th>
<th>Test case 5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE mesh mean error ± std (mm)</td>
<td>0.80 ± 0.64</td>
<td>0.79 ± 0.74</td>
<td>1.07 ± 1.33</td>
<td>0.54 ± 0.3</td>
<td>0.96 ± 1.14</td>
<td>0.83 ± 0.91</td>
</tr>
<tr>
<td>Mean DICE bone</td>
<td>0.907</td>
<td>0.951</td>
<td>0.947</td>
<td>0.955</td>
<td>0.936</td>
<td>0.940</td>
</tr>
<tr>
<td>Mean DICE cartilage</td>
<td>0.760</td>
<td>0.813</td>
<td>0.755</td>
<td>0.755</td>
<td>0.675</td>
<td>0.751</td>
</tr>
<tr>
<td>Segmentation time</td>
<td>02m 25s</td>
<td>01m 56s</td>
<td>02m 14s</td>
<td>03m 27s</td>
<td>03m 27s</td>
<td>02m 42s</td>
</tr>
<tr>
<td>FE mesh generation time</td>
<td>16m 6s</td>
<td>16m 43s</td>
<td>18m 16s</td>
<td>17m 31s</td>
<td>16m 23s</td>
<td>17m 00s</td>
</tr>
</tbody>
</table>
Next steps:

Training set

Baldwin et al. (2009)
THANK YOU

Acknowledgements:

https://simtk.org/projects/kneehub

KneeHub Collaborators:

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