Patellar instability
● What it is: A clinical syndrome where the patella bone disarticulates from the patellofemoral joint in the knee
● Who it affects: Adolescents ages 14-18, with ~148 cases per 100,000
● How it’s measured: Patellar tilt is the angle between the condyle (lateral to medial) line and the patella (lateral to medial) line
● How surgery decisions are made: 10 ± 4.3° is normal, and surgically viable cases are 16 ± 3.3°
● Why deep learning can help: Radiologist labels suffer from inter-observer variation

Dataset
● Source: JUPITER (JUstifying Patellar Instability Treatment by Early Results) group, a subset from Cincinnati Children’s Hospital Medical Center
● Size: 216 MRI volumes
● Dimensions: ~30 slices per MRI, 256 x 256 to 1024 x 1024 pixels each
● Split: 80% train, 20% test, no validation

Background

U-Net
● What it is: A fully convolutional architecture with symmetrical contractive and expansive paths
● Model type: Segmentation
● Input: Any sized 3 channel image
● Output: Same size as input, but with k output channels for the k classes
● Advantages: Scales to any input, works well with elastic deformations for small datasets

Elastic deformation
● What it is: A data augmentation technique to produce new training samples
● Input: Any sized 3 channel image
● Output: Input perturbed by random vector displacement
● Advantages: Low memory overhead, trains model to be invariant to deformed tissue

Training
● What: 4 U-Nets initialized with pretrained weights
● How: Adam optimizer, 5 x 10⁻³ learning rate, 32 batch size, 100 epochs
● Loss: Cross entropy

Prediction
● Given: Prediction mask
● How: Softmax over class channels, blur, max localization
● Output: x-y keypoint coordinates

Difficulties
● Multiple or no bright spots in predicted keypoint masks
  ○ Solution: Train for more epochs
  ○ Solution: Replace outliers with training median
● Predicted mask won’t converged, still looks like input
  ○ Solution: Relax elastic deformation strength

Results

Keypoint coordinates
● Measure of error: L2 distance
● Baseline (modified ResNet): 20 pixels average error

<table>
<thead>
<tr>
<th>Keypoint model</th>
<th>Number of Outliers</th>
<th>Error (pixels)</th>
<th>Avg.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral condyle</td>
<td>1</td>
<td>3.395</td>
<td>26.653</td>
<td></td>
</tr>
<tr>
<td>Medial condyle</td>
<td>3</td>
<td>2.885</td>
<td>27.625</td>
<td></td>
</tr>
<tr>
<td>Lateral patella</td>
<td>2</td>
<td>2.445</td>
<td>8.285</td>
<td></td>
</tr>
<tr>
<td>Medial patella</td>
<td>1</td>
<td>2.568</td>
<td>15.987</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Keypoint prediction error statistics.

Patellar Tilt
● Measure of error: intraclass correlation coefficient (ICC)
● Baseline: Human vs. Human

Model | ICC
---|---
U-Net vs. Human | 0.555
U-Net (augmented data) vs. Human | 0.768
Human vs. Human | 0.816

Table 2. Patellar tilt reliability results.