X-Ray Image Segmentation of the Hip Joint

Segmentation of the hip joint space based on a radial projection originating from the center of the femoral head

Kees Blok
C.blok-1@student.tudelft.nl

TU Delft Delft University of Technology

INTRODUCTION

Osteoarthritis (OA) is a growing health problem. In 2021, 1.589.600 people were estimate to have OA in the Netherlands [1]

X-ray images are often used in the diagnosing process.

- The minimum distance between the bones in the hip joint, the minimum joint space width (JSW), is most strongly associated with OA in X-ray images [2].
- For knee OA multiple-JSW has been proven to be even stronger associated [3].
- This might also be the case for hip OA.
- Accurate segmentation of joint space is required to calculate the joint space profile.

A radial projection of an image maps circular lines to straight lines.

The aim of this research was to investigate how the joint space profile can be segmented most accurately from a radial projection originating from the center of the femoral head by comparing multiple noise filtering and edge-finding algorithms.

METHODOLOGY

- Comparison of multiple denoising filters
- Comparison of multiple edge-finding algorithms
- Development of custom edge-finding algorithm

See the figure 1 for the full pipeline.

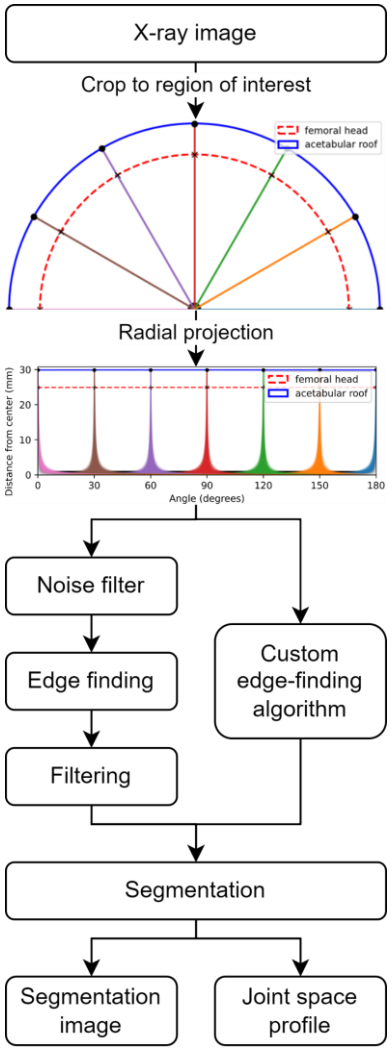

Figure 1, segmentation pipeline

EXPERIMENTAL SETUP

Output of algorithms are compared to landmark points created by BoneFinder [4].

Custom edge-finding algorithm:

- Finds the strongest gradients. Those correspond to the edges of the femoral head and acetabular roof.
- Uses moving average to smoothen out outliers.

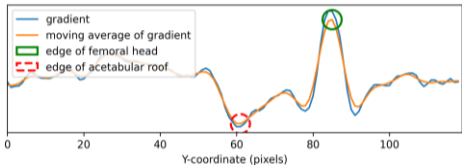

Figure 2, gradient of intensities & selected peaks

RESULTS & DISCUSSION

Best performing algorithms:

- Custom edge-finding algorithm
- Difference of Gaussians followed by minimum cross entropy thresholding

Points of improvement:

- Roughness of edges
- Detection start of femoral head

Can be used:

- To measure (minimum) JSW automatically and consistently.
- In research if full joint space is a better estimator for hip OA than minimum JSW.

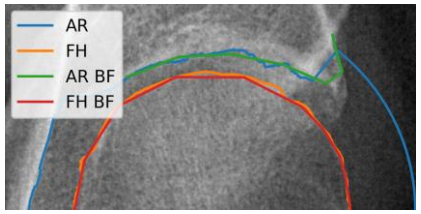

Figure 3, segmentation using custom edge-finding algorithm

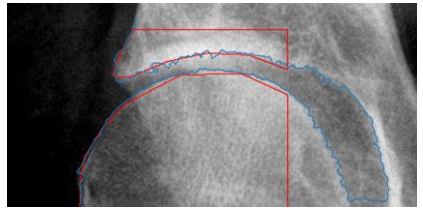

Figure 4, segmentation using difference of Gaussians and minimum cross entropy thresholding

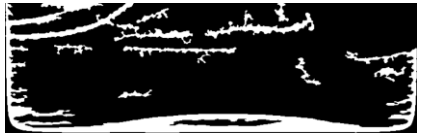

Figure 5, edges missing in segmentation

CONCLUSION

Difference of Gaussians followed by minimum cross entropy thresholding:

- Gives reasonably good results.
- Small blobs are removed, which are sometimes also part of the actual edge. This results in an incomplete segmentation.
- Edges are too rough

Custom edge-finding algorithm:

- Most reliable and consistent results since it always outputs an edge for the femoral head and acetabular roof.
- Most accurate for weight-bearing part of femoral head.
- Larger errors at lateral side of femoral head due to irregularities in density and shape.
- Start of acetabulum is often incorrect due to not having the a strong edge.

Other noise removing and edge-preserving filters do not work well with X-ray images:

- Keep too much noise.
- Smoothen out the actual edges.

References
[1] Vanhommerig, J., Poos, M., Gommer, A., Hendriks, C., & Giesbers, H. (2022, November). Artrose | Leeftijd en geslacht | Volksgezondheid en Zorg. Retrieved 2024-04-22, from https://www.vzinfo.nl/ artrose/leeftijd-en-geslacht
[2] Croft, P., Cooper, C., Wickham, C., & Coggon, D. (1990, September). Defining osteoarthritis of the hip for epidemiologic studies. American Journal of Epidemiology, 132(3), 514–522. doi: 10.1093/oxfordjournals.aje.a115687
[3] Cheung, J. C.-W., Tam, A. Y.-C., Chan, L.-C., Chan, P.-K., & Wen, C. (2021, October). Superiority of MultipleJoint Space Width over Minimum-Joint Space Width Approach in the Machine Learning for Radiographic Severity and Knee Osteoarthritis Progression. Biology, 10(11), 1107. doi: 10.3390/biology10111107
[4] Lindner, C., Thiagarajah, S., Wilkinson, J. M., Wallis, G. A., & Cootes, T. F. (2013). Fully automatic segmentation of the proximal femur using random forest regression voting. IEEE Transactions on Medical Imaging, 32(8), 1462–1472. Retrieved 2024-06-10, from https://research.manchester.ac.uk/en/publications/fully-automatic-segmentation-of-the-proximal-femur-using-random-f (Publisher: IEEE) doi: 10.1109/TMI.2013.2258030