Detection of joint space narrowing in hand radiographs

J.A. Kauffman¹, C.H. Slump¹, H.J. Bernelet Moens²

¹ Signals and Systems Group
Department of Electrical Engineering, Mathematics and Computer Science
University of Twente, Enschede, <http://www.sas.el.utwente.nl>, email: j.a.kauffman@utwente.nl

² Department of Rheumatology
Ziekenhuis Groep Twente, Hengelo/Almelo

University of Twente
Enschede - The Netherlands

Introduction

Research goal

Joint damage assessment in hand radiographs to determine progression of **rheumatoid arthritis**.

Joint space narrowing

Inflammation of the synovial membrane releases enzymes that break down cartilage. This effect can be monitored indirectly by measuring the distance between the joint margins: **the joint space width (JSW)**.

example of joint damage progression (left to right, 2y intervals)

Problems with manual methods

- intra/inter-reader variability
- time consuming
- missing golden standard

Proposed solution

Automated detection of joint margins with high reproducibility.

Margin characteristics

Training set

- 50 hand radiographs
- 8 locations: metacarpophalangeal joints 2-5 and proximal interphalangeal joints 2-5
- manually outlined joint margins

Active shape model [1]

- 25 equidistant points per margin over 6mm
- 8 modes of variation

manual outlining and landmarks

Profile characterization

- 25 intensity profiles perpendicular to margin
- 15 samples per mm
- mean and variance estimation

intensity profile lines

intensity profiles of proximal margin

Search method

1. Initialization by 8 points on proximal and distal ends of proximal phalanges (PP). Automated initialization with segmentation method [2].
2. Initial estimate of margin is mean of shape model. Orientation is aligned with PP-axis.
3. Profiles are scanned perpendicular to margin.
4. Mahalanobis distance determines likely margin locations in cost matrix.
5. Minimum cost path is calculated with dynamic programming method.

initialization points

calculation of minimum cost path

6. New margin points are projected into model space and back to find plausible shape.
7. Repeat steps 3-6 4x to reach convergence.

Results

Test set

50 images of patients that were not in the training set.
Difference measure: the mean of the absolute distances between margins.

Margin detection

Reproducibility;
manual: < 0.14 mm (90%)
automated: < 0.071 mm (90%)
Difference;
manual/automated: < 0.12 mm (90%)

JSW measurements

Reproducibility;
manual method < 0.20 mm (90%)
automated method < 0.065 mm (90%)
Difference;
manual/automated < 0.14 mm (90%)

example result from test set

overall JSW differences

JSW reproducibility per joint with automated method

Conclusions

- Robust and precise method for visible joint margins. Fails in cases of severe joint damage.
- Automated method has better reproducibility and is more accurate than manual method.
- Shape model constraints prevent detection of false margins, but also limit the detection of unusual margin shapes.

References

- [1] Cootes, T. F., Hill, A., Taylor, C. J., and Haslam, J., "Use of active shape models for locating structure in medical images", *Image and Vision Computing*, vol. 12, no. 6, pp. 355-365, 1994.
- [2] Kauffman, J. A., Slump, C. H., and Bernelet Moens, H. J., "Segmentation of hand radiographs with multilevel connected active appearance models", *Medical Imaging 2005: Image Processing* 5747-182. 2005. SPIE.
- [3] Amini, A. A., Weymouth, T. E., and Jain, R. C., "Using dynamic programming for solving variational problems in vision", *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 12, no. 9, pp. 855-867, 1990.

This study is supported by a grant
from the Dutch Arthritis Association:

Reumafonds
Sterk in beweging