Extra information on: Finger analysis in video using multi-scale ridge detection

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Introduction

Eye tracking is widely used in psychological research (figure 1). There are many cases in which hand and finger tracking would be very useful. Single-camera machine vision approaches are desirable for their use of non-specialized hardware, and usability in unrestricted environments. We adopted a multi-scalar ridge detection algorithm to enable robust finger tracking in such a setting.

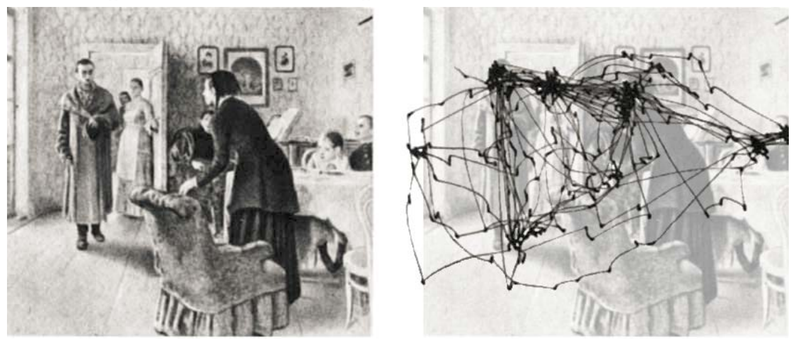

figure 1. eye-tracking (adapted from DeAngelus and Pelz, 2009)

Intrinsic geometry and ridge detection

Our algorithm uses the intrinsic geometry of the images fixing the local coordinate system *(v,w)* to the local image gradient (figure 2a). The second Gaussian derivative L_{vv} is a good operator for detecting ridges (figure 2b and 3). In image analysis, as scale varies different geometries become apparent (figure 2c). We used this in our algorithm to detect arms and fingertips (figure 4).

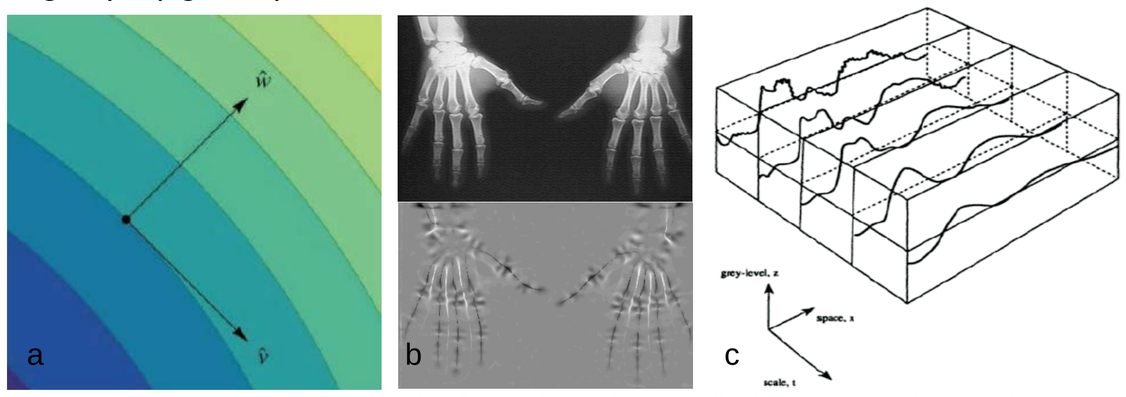

figure 2. a: intrinsic geometry. b: ridge detection applied to a X-ray image (Ter Haar Romeny and Florack, 2000). c: scale-space illustration of a one-dimensional signal (Lindeberg, 1994).

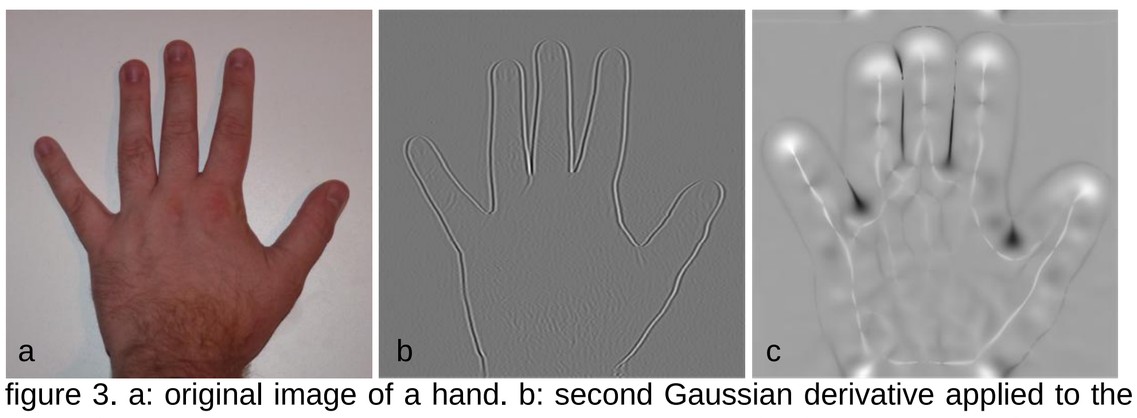

figure 3. a: original image of a hand. b: second Gaussian derivative applied to the original image in the extrinsic coordinate system *(x,y)*. c: second Gaussian derivative in the local intrinsic gauge coordinate system *(v,w)*.

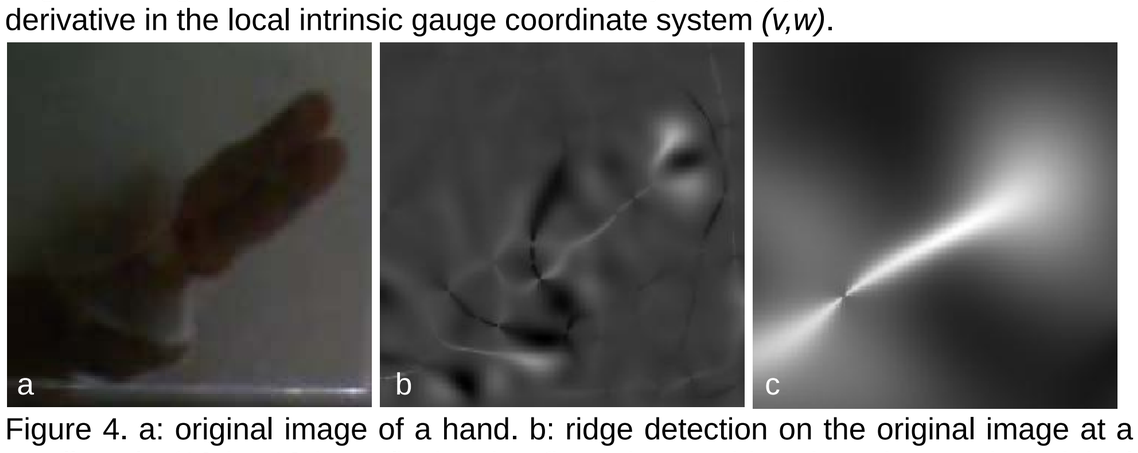

Figure 4. a: original image of a hand. b: ridge detection on the original image at a small scale (12 by 12 kernel) showing fingertips. c: ridge detection on the original image at a larger scale (200 by 200 kernel) showing a different geometry: the hand.

Methods

The algorithm we used for our analysis is:
1 Import and crop images. 2 Convert to grayscale. 3 Subtract background image from image. 4 Apply Gaussian 200 by 200 pixel L_{vv} kernel. 5 Threshold arm. 6 Locate top of arm. 7 Select a 50 by 50 pixel subset around the top of arm. 8 Apply Gaussian 12 by 12 pixel L_{vv} kernel. 9 Threshold for fingertips. 10 Erode twice. 11 Cluster. 12 Calculate mean of clusters. 13 Calculate the path.
We used Mathematica 8 with the add-on MathVisionTools for this analysis.

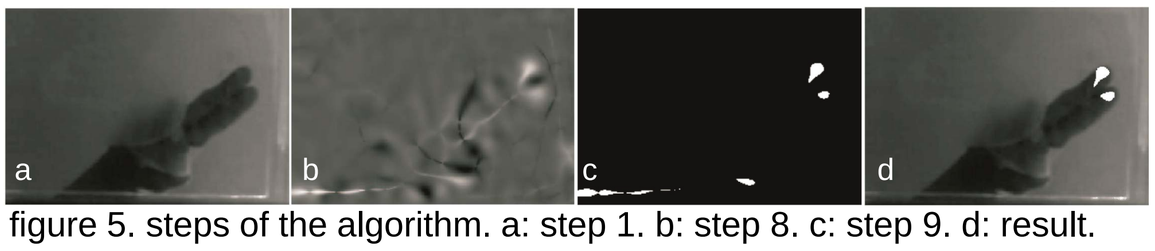

figure 5. steps of the algorithm. a: step 1. b: step 8. c: step 9. d: result.

Data

We have videos of 14 volunteers performing tasks with tactile maps. Figure 6 shows finger-tracking results from one of these trials, in which the subject was asked to determine if there was a loop in the walking path.

Results

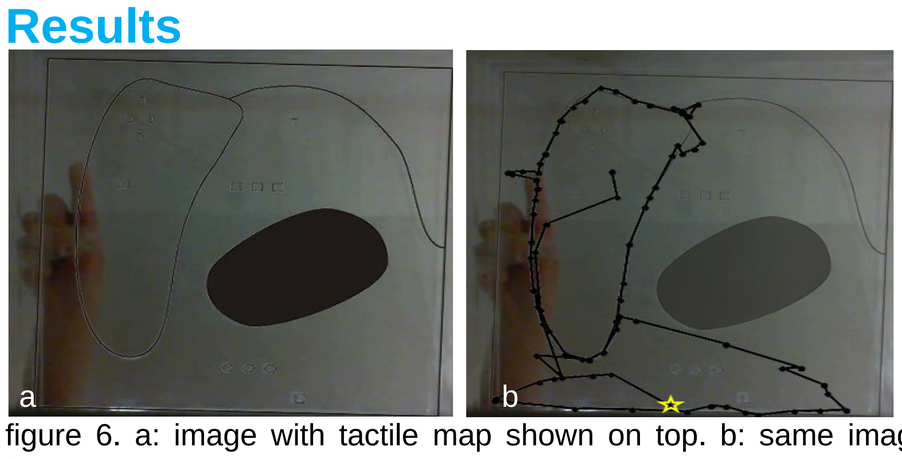

figure 6. a: image with tactile map shown on top. b: same image with the path followed by the volunteer shown on top, the star is the starting point.

Percent on border: 18 %
Percent on empty space: 20 %
Percent on loop: 62 %

Conclusion

We have developed a robust method to quantify the path of peoples fingertips in video, and can indentify with which parts of the stimuli the fingertips are in contact.

Discussion

Benefits of our approach are that we do not need fiducial markers or special cameras, and our algorithm is effective in a relatively uncontrolled environment. Our results suggest that ridge detection could provide psychological researchers with an effective tool for hand and finger tracking.

References

- DeAngelus, M., Pelz, J. (2009), Top-down control of eye movements: Yarbus revisited, *Visual Cognition, 17(22), 790-811*
-ter Haar Romeny, B., Florack, L. (2000), Front End Vision: A Multiscale Geometry Engine, *Lecture Notes in Computer Science, 373 – 384*
- Lindeberg (1994), *Scale-Space Theory in Computer Vision.* Kluwer Academic Publishers/Springer, Dordrecht, Netherlands.

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