Trainable COSFIRE filters for keypoint detection object localization, and pattern recognition

Authors: George Azzopardi, Nicolai Petkov
Emails: {g.azzopardi, n.petkov}@rug.nl
Affiliation: Johann Bernoulli Institute for Mathematics and Computer Science

university of groningen

Contribution

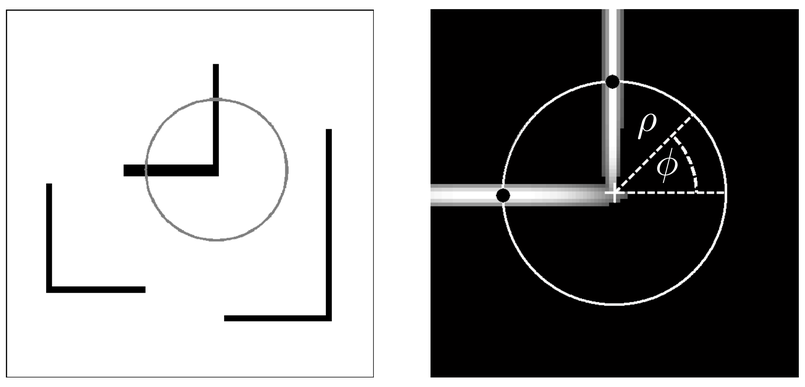
- COSFIRE: **C**ombination **o**f **S**hifted **Fi**lter **Re**sponses [1]
- A COSFIRE filter is selective for the geometrical arrangement of edges/lines of a prototype shape of interest
- Trainable: its selectivity is determined from a single prototype in an automatic configuration process
- Tolerant to *rotation*, *scale* and *reflection*

Motivation

- Some neurons in area V4 of visual cortex are selective to combinations of edges/lines [2]
- Corners and junctions are present in many types of images

Configuration

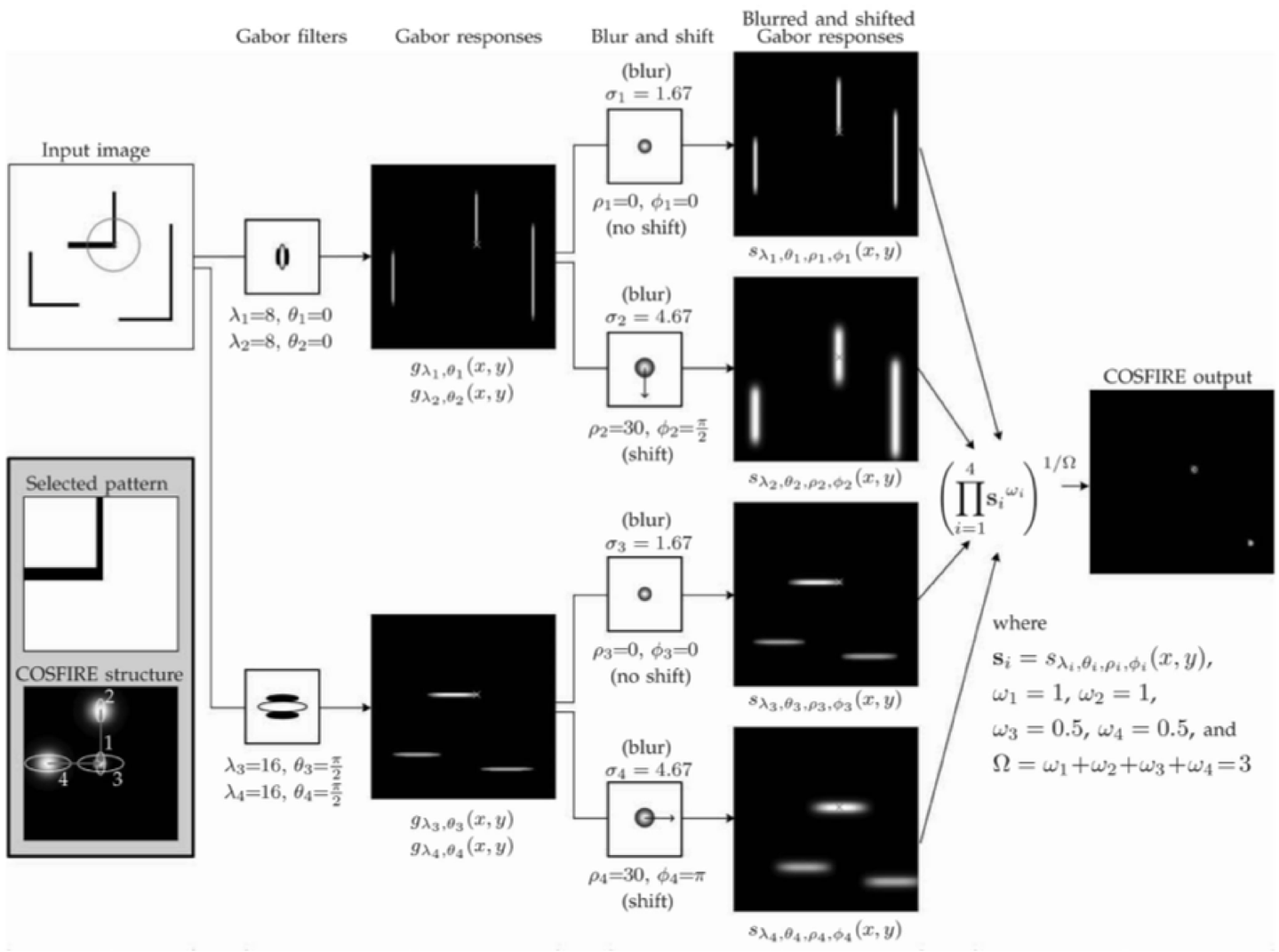
Example of a corner-selective COSFIRE filter



1. Let the encircled corner be a prototype pattern
2. Apply a bank of Gabor filters to the prototype
3. Extract Gabor parameter values (λ_i, θ_i) at local maxima points along some circle(s)
4. Extract polar coordinates (ρ_i, ϕ_i) of local maxima points *wrt* to the location indicated by a '+'
5. Result is a set $S_f = \{(\lambda_i, \theta_i, \rho_i, \phi_i) \mid i = 1 \dots n_f\}$
6. For the considered example:

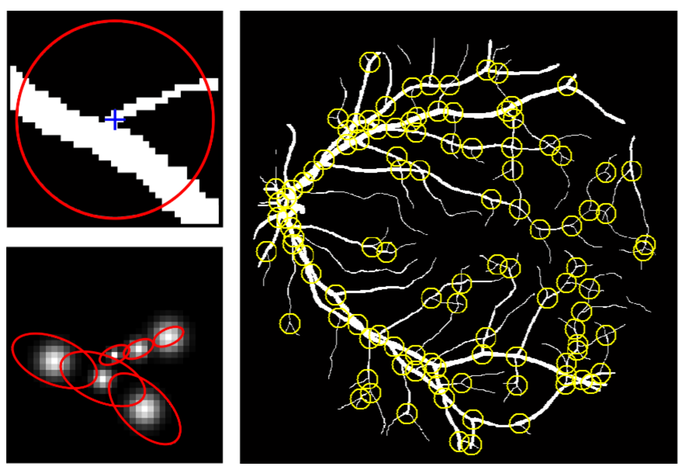
$$S_f = \left\{ \begin{array}{llll} (\lambda_1 = 8, & \theta_1 = 0, & \rho_1 = 0, & \phi_1 = 0), \\ (\lambda_2 = 8, & \theta_2 = 0, & \rho_2 = 30, & \phi_2 = \frac{\pi}{2}), \\ (\lambda_3 = 16, & \theta_3 = \frac{\pi}{2}, & \rho_3 = 0, & \phi_3 = 0), \\ (\lambda_4 = 16, & \theta_4 = \frac{\pi}{2}, & \rho_4 = 30, & \phi_4 = \pi) \end{array} \right\}$$

Response of a COSFIRE filter



Applications and results

Bifurcation detection in retinal images

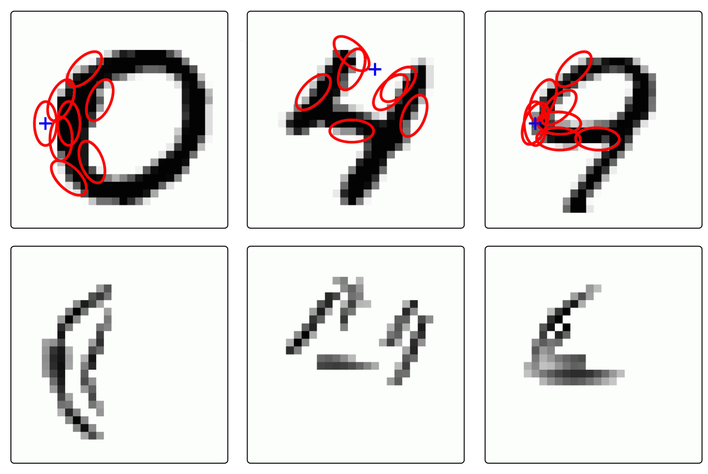


DRIVE data set: 40 retinal images
98.5% recall, 96.09% precision

Traffic sign detection and recognition

RuG data set: 48 images, 3 kinds of traffic signs
100% recall, 100% precision

Handwritten digit recognition



MNIST data set: 70,000 images
98.48% recognition rate

Conclusions

- COSFIRE filters are highly effective for keypoint detection, object localization in complex scenes, and pattern recognition
- Versatile: suitable to many computer vision applications
- Conceptually simple and easy to implement
- Matlab code: http://matlabserver.cs.rug.nl/cosfireweb/web/

References

[1] G Azzopardi and N Petkov. "Trainable COSFIRE Filters for Keypoint Detection and Pattern Recognition". In: *IEEE Transactions on Pattern Analysis and Machine Intelligence* 35.2 (2013), 490–503.

[2] A Pasupathy and CE Connor. "Responses to contour features in macaque area V4". In: *Journal of Neurophysiology* 82.5 (1999), 2490–2502.