COSFIRE MODELS FOR DESCRIBING OBJECTS AS ARRANGEMENTS OF CIRCULAR REGIONS

Gecer B. - Bilkent University, Azzopardi G. - University of Malta, Petkov N. - University of Groningen
baris.gecer@cs.bilkent.edu.tr, george.azzopardi@um.edu.mt, n.petkov@rug.nl

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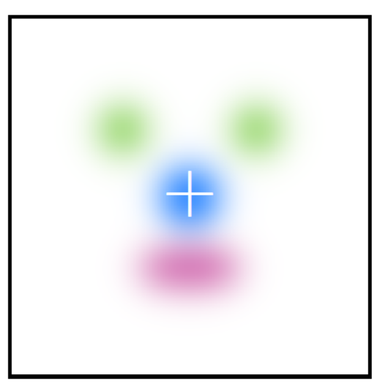
Abstract

We propose blob-based C-COSFIRE filters to model a given object of interest in terms of diffuse circular regions in a specific mutual spatial arrangement.
A C-COSFIRE filter combines the responses of a collection of DoG filters of different scales, in all dimensions of a color space, and at certain relative positions. Its parameters are determined in an automatic configuration process that analyses the properties of a given object of interest. We show its effectiveness on two benchmark data sets.

Automatic Configuration

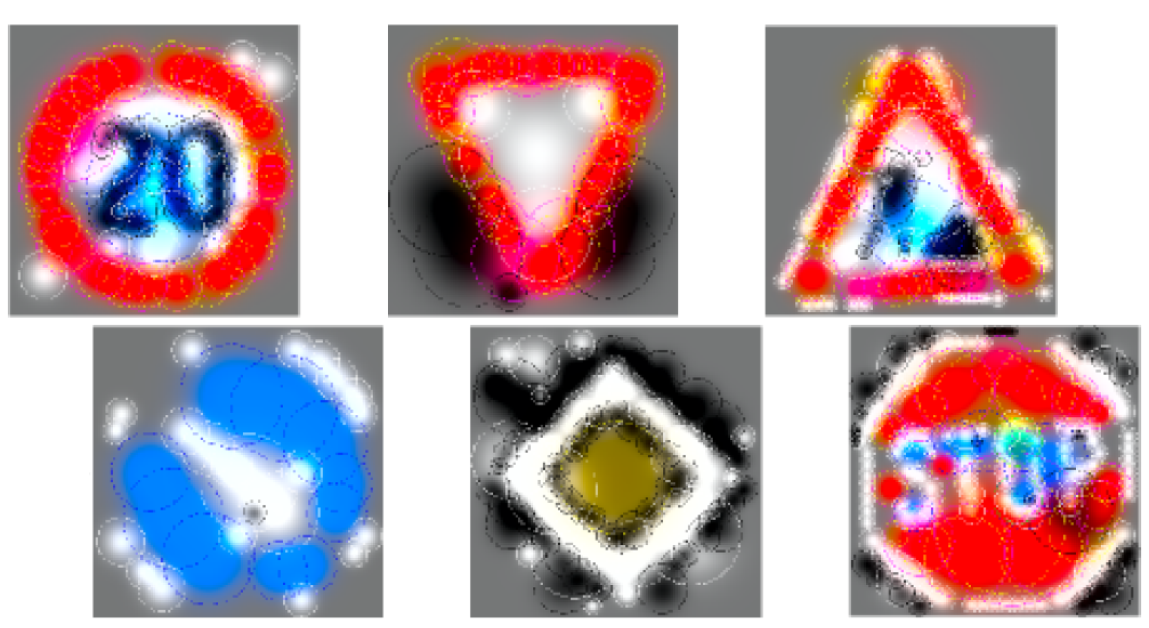
Main steps :

1. Transform a single prototype pattern into a color space (L*a*b*)
2. Detect blobs in each color channel using DoG filters
3. Extract the properties of the detected blobs (DoG) together with their mutual spatial arrangement.



$$\Rightarrow \left\{ \begin{array}{l}
(\alpha_1 = \mathrm{a}^*, \sigma_1 = 84, \delta_1 = +, \rho_1 = 161, \phi_1 = 3\pi/2), \\
(\alpha_2 = \mathrm{a}^*, \sigma_2 = 99, \delta_2 = +, \rho_2 = 180, \phi_2 = 8\pi/5), \\
(\alpha_3 = \mathrm{a}^*, \sigma_3 = 99, \delta_3 = +, \rho_3 = 180, \phi_3 = 7\pi/5), \\
(\alpha_4 = \mathrm{a}^*, \sigma_4 = 69, \delta_4 = -, \rho_4 = 211, \phi_4 = 3\pi/4), \\
(\alpha_5 = \mathrm{a}^*, \sigma_5 = 69, \delta_5 = -, \rho_5 = 211, \phi_5 = \pi/4), \\
(\alpha_6 = \mathrm{b}^*, \sigma_6 = 81, \delta_6 = +, \rho_6 = 204, \phi_6 = \pi/4), \\
(\alpha_7 = \mathrm{b}^*, \sigma_7 = 81, \delta_7 = +, \rho_7 = 204, \phi_7 = 3\pi/4), \\
(\alpha_8 = \mathrm{b}^*, \sigma_8 = 84, \delta_8 = -, \rho_8 = 4, \phi_8 = \pi/2), \\
(\alpha_9 = \mathrm{L}^*, \sigma_9 = 81, \delta_9 = +, \rho_9 = 149, \phi_9 = 1.9\pi), \\
(\alpha_{10} = \mathrm{L}^*, \sigma_{10} = 81, \delta_{10} = +, \rho_{10} = 150, \phi_{10} = 1.1\pi), \\
(\alpha_{11} = \mathrm{L}^*, \sigma_{11} = 75, \delta_{11} = +, \rho_{11} = 150, \phi_{11} = \pi/2)
\end{array} \right\}$$

Configuration Examples



References

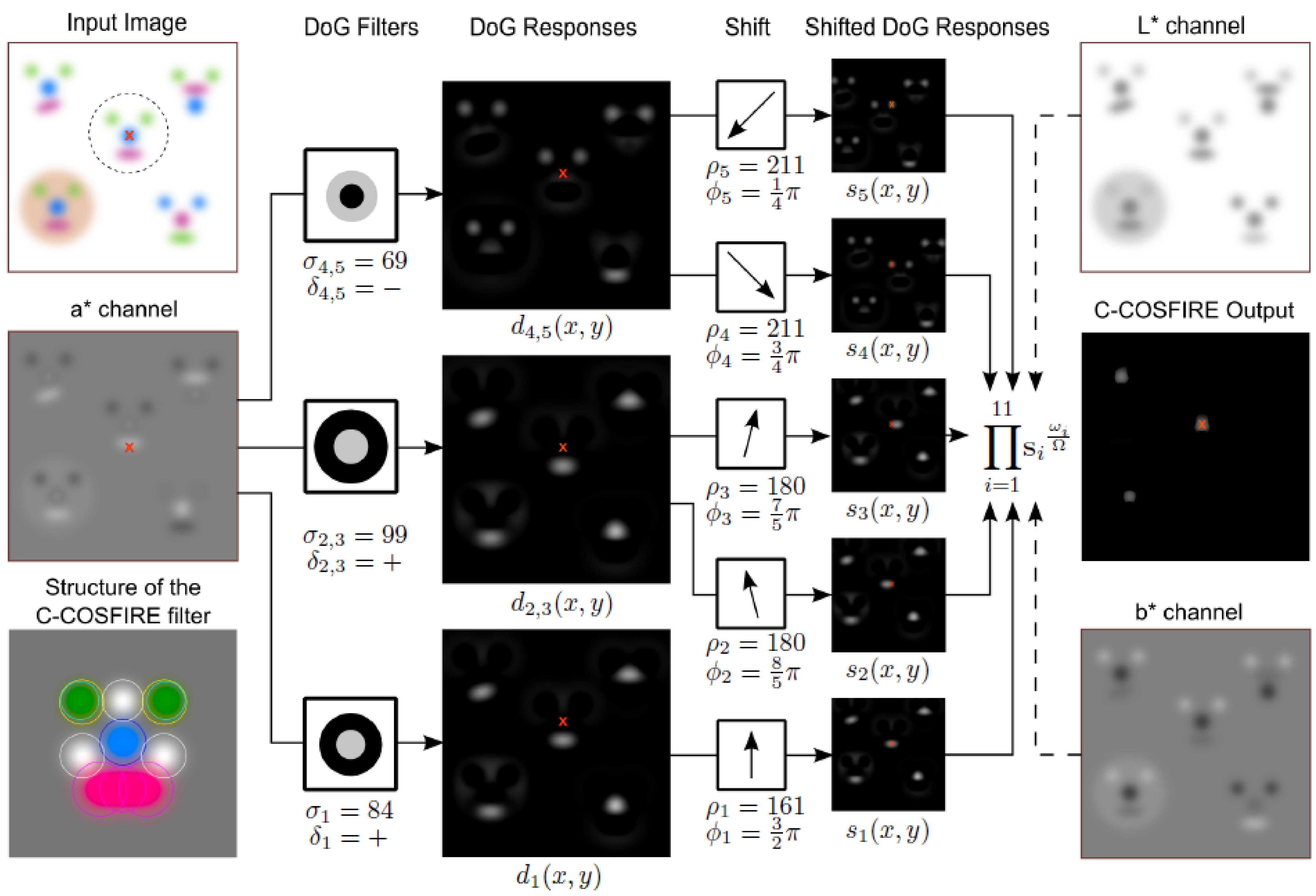
[1] G. Azzopardi, N. Petkov, Trainable COSFIRE filters for keypoint detection and pattern recognition, in *IEEE PAMI*, 2013

[2] J. Stallkamp, M. Schlipsing, J. Salmen, C. Igel, The German Traffic Sign Recognition Benchmark: A multi-class classification competition, in *IEEE IJCNN*, 2011

[3] S. Lazebnik, C. Schmid, J. Ponce, Semi-local affine parts for object recognition, in *BMVC*, 2004

Applying C-COSFIRE Filter to an Image

- Responds where a pattern is present which is similar to the prototype pattern
- Output is computed by the weighted geometric mean of shifted DoG responses



The above figure shows an example of the processing of the first five tuples of a C-COSFIRE filter whose structure is illustrated at the bottom-left corner :

1. Apply mutual three DoG filters to a* channel
2. Shift DoG responses according to the configuration
3. Compute the weighted geometric mean of all the shifted DoG filter responses (including L* and b* channels)

Experiments: Traffic Signs and Butterflies

For both data sets, we follow the following procedure :

1. Configure several C-COSFIRE filters to be selective for patterns (partially or entirely) extracted from the training set.
2. Use their responses to form feature vectors
3. Train a multi-class SVM classifier with linear kernel.

German Traffic Sign Recognition Benchmark (GTSRB) Data Set [2] :

- 43 categories, 51839 images
- 98.94% recognition rate is achieved
- Perform better than human subjects

Multi-column deep NN	99.46%
Proposed Method	98.94%
Human Performance	98.84%
Multi-Scale CNNs	98.31%
COSFIRE[1] on gray-scale	90.68%

The Butterfly Data Set [3] :

- 7 categories, 619 images
- 89.02% recognition rate is achieved
- Best performance is 90.4%
- Below, a partial C-COSFIRE filter on a butterfly and its corresponding response for the middle image