COSFIRE: A trainable features approach to pattern recognition

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In a recent work (Azzopardi & Petkov, 2013), we proposed a trainable features approach to visual pattern recognition. It is called COSFIRE, which stands for Combination of Shifted Filter Responses.

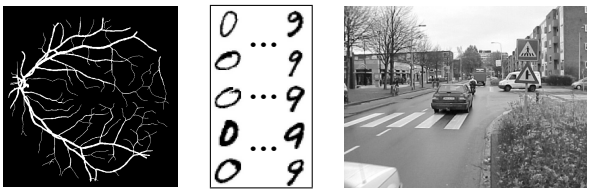
A COSFIRE operator is automatically configured by a specified pattern of interest, referred to as a prototype, and is then able to detect the same and similar patterns in other images. The configuration comprises the determination of the orientations of dominant contour parts and their mutual spatial arrangement.

The output of a COSFIRE operator is computed as the weighted geometric mean of simpler filter responses (e.g. Gabor filters), the properties of which are determined in the configuration stage. COSFIRE operators also achieve tolerance to rotation, scale and reflection.

We demonstrated the effectiveness of the proposed filters in three applications, Fig. 1: the detection of vascular bifurcations in segmented retinal images (DRIVE data set: recall of 97.88% at precision of 96.94%), the recognition of isolated handwritten digits (MNIST data set: 99.48% correct classification), and the detection and recognition of traffic signs in complex scenes (100% recall and 100% precision).

The area of support of a COSFIRE operator is adaptive as it is composed of the support of a number of orientation-selective filters whose relative geometrical arrangement is learned from a given prototype pattern. In contrast, the area of support of other operators, such as SIFT, is typically a square window, the size of which is related to the appropriate scale of the concerned pattern. The presence of noise around a pattern of interest has little or no affect on the output of a COSFIRE operator. Other operators may, however, result in a descriptor that may differ substantially from the descriptor of the same but noiseless pattern.

The proposed COSFIRE operators share similar properties with some shape-selective neurons in visual cortex (Pasupathy & Connor, 1999), which provided inspiration for this work. They are versatile detectors, conceptually simple, easy to implement and are highly effective in practical computer vision applications[1].



(a) (b) (c)

Figure 1. COSFIRE operators are effectively applied to three applications: (a) detection of vascular bifurcations in segmented retinal images, (b) recognition of handwritten digits and (c) spotting of traffic signs in complex scenes.

The COSFIRE approach to feature definition contains an interesting aspect from a machine learning point of view. In traditional machine learning the features to be used are typically predefined and are used to derive other features as (linear) combinations of the original ones with techniques, such as PCA and ICA. With the proposed approach, however, the appropriate prototype features are learned in the configuration of the corresponding COSFIRE operators.

References

Azzopardi, G., & Petkov, N. (2013). Trainable COSFIRE Filters for Keypoint Detection and Pattern Recognition. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *35*, 490–503.

Pasupathy, A., & Connor, C. E. (1999). Responses to contour features in macaque area v4. *Journal of Neurophysiology*, *82*, 2490–2502.

[1]Matlab code: http://matlabserver.cs.rug.nl