Edge detection via fuzzy switch

Edge detection is the first step for some boundary extraction and boundary representation algorithms. It has been playing an important role in image recognition and data retrieval problems. For example, in the processing of cancer cell images, once the edges of the cancer cells are detected, the shapes of the cancer cells can be seen more clearly. As the shapes of the cancer cells provide useful information for the medical professionals to decide the types of the cancer cells, thus, the technique helps to reduce the time and improves the accuracy for the diagnosis procedure.

Some traditional methods, such as, Sobel filter, Prewitt filter, Roberts filter, Isotropic filter and Canny filter, were proposed. These methods were based on convoluting an image with the impulse response of a linear spatial-invariant filter, which approximates either the first or the second order derivatives. However, when the image is suffered from noise, there is a tradeoff between the detection error (signal-to-noise ratio) and the localization (the reciprocal of the root-mean-squared distance of the marked edge from the center of the true edge), and the optimal filter is the derivative of a Gaussian filter.

In order to work on this problem, a composition of conditioning, feature extraction, blending and scaling is proposed in Reference 1. Conditioning is to enhance the raw sensor data for further processing. Some examples of conditioning are contrast enhancement and histogram equalization. Feature extraction is to extract feature vectors that represent an edge information. The most common features are the Sobel features, the Prewitt features and the range and standard deviation features. Blending is to aggregate components of feature vectors. The inner product or

Minkowski norms, the generalized logistic functions, such as waterfall functions, and computational learning models, such as neural-like network models and Takagi-Sugeno fuzzy reasoning models, are used in the Reference. Finally, scaling is to scale a raw edge image to get gray levels or crisp points. Dynamic scaling is employed in the Reference.

However, different feature vectors have different properties at the edge points. For example, Sobel features approximate a first order derivative, and hence give a maximum value at an edge point. On the other hand, Laplace features approximate a second order derivative, which is zero at an edge point. As a result, we should consider these properties when designing some blending functions to aggregate different components of the feature vectors together. Moreover, if a blending function gives a weighted sum of each element in the feature vectors, then the edge will be blurred because a weighted approach will introduce a lowpass effect at the output.

Instead, we model an edge detector as a fuzzy switch shown in figure 1. The expert systems are the edge detectors that capture the knowledge from different experts. The outputs of the expert systems form a feature vector that provides useful edge information. The fuzzifiers are to normalize the values of the elements in the feature vector. The fuzzy engine (fuzzy switch) is to aggregate the components of the feature vectors and the defuzzifier is to map the output of a fuzzy engine to a crisp point that represents an edge point.

For the expert systems, we have selected the common gradient operators and compass operators, such as the Sobel filter, Prewitt filter, Roberts filter, Isotopic filter, Canny filter and Kirsch filter. For the blending function, we have selected the maximum value in the feature vector.

Results

We have tested a 512x512 image 'Cancer', using the well-known gradient operators: the Sobel filter, Prewitt filter, Roberts filter, Isotropic filter and Canny filter, as well as our proposed algorithm. The simulation results show that the Canny edge detector produces too many details that the skeletons of the images are lost, and gives noisy outputs in some regions. On the other hand, the Prewitt filter and Roberts filter produce too little information on the outputs, so the edges are mainly discontinuous. In comparison, our proposed algorithm captures the advantages of the different expert systems, and so it produces the best results.

References

1. J. C. Bezdek, R. Chandraskhar and Y. Attikiouzel, *A Geometric Approach to Edge Detection*, **IEEE Transactions on Fuzzy Systems**, **6** (1), pp. 52-75, February, 1998.

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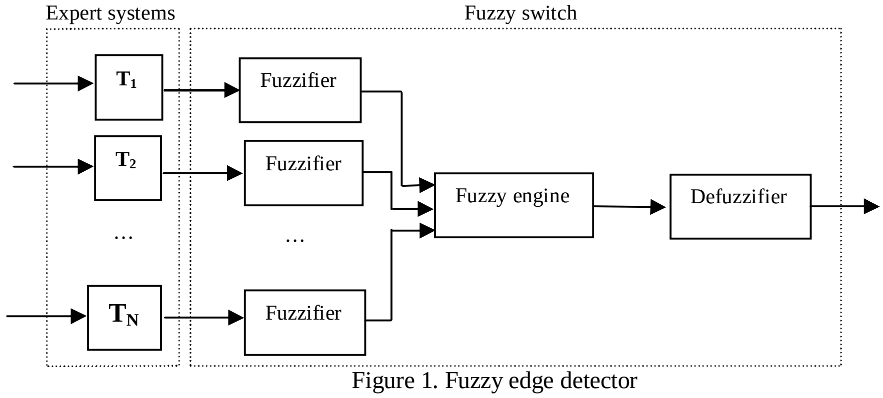

Figure 1. Fuzzy edge detector

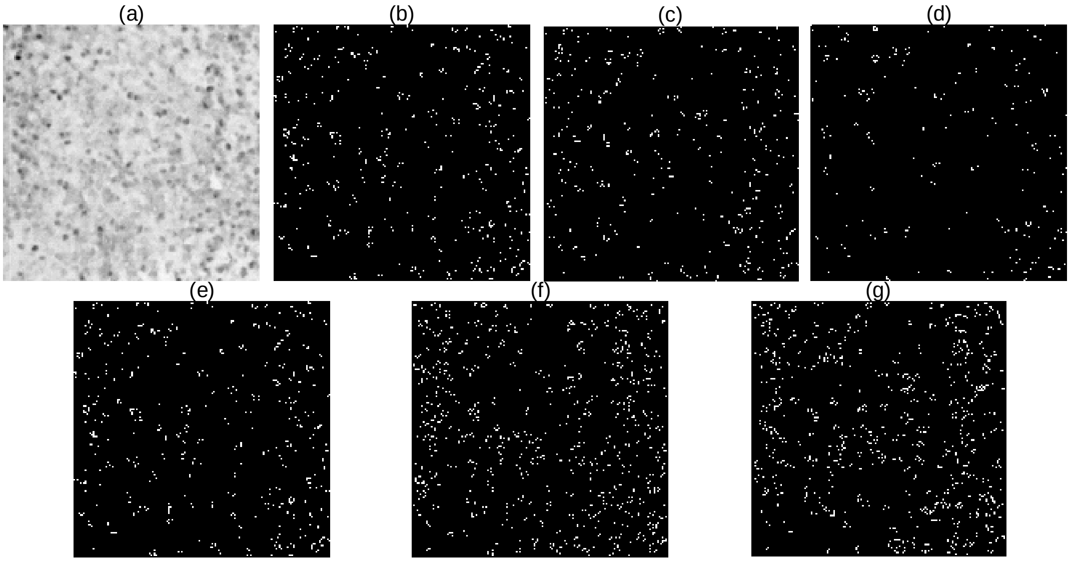

Figure 2. Results of different edge detectors on the image "Cancer". (a) original image (b) output of Sobel filter (c) output of Prewitt filter (d) output of Roberts filter (e) output of Isotropic filter (f) output of Canny filter (g) output of our proposed fuzzy switch