

# List of algorithms used in graphical analysis

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## 1 Algorithms

### 1.1 Edge Detection

Edge detection algorithms all use what are called convolution kernels. A kernel in image processing is a small matrix used to apply effects to an image, such as blurring, outlining. Here we will see kernels used for edge detection only. Listed below are six of the best and most used algorithms.

- Sobel
- Frei-Chen
- Prewitt
- Roberts Cross
- LoG
- Scharr

#### 1.1.1 Convolution kernel

Since all the algorithms are based on the mathematical principle of convolution, some explanation of these convolution kernels is in order.

Convolution is the technique of multiplying together two arrays of different size but of the same dimension. One of the two arrays used in the calculation is the numerical representation of the image (pixels) on which we

want to perform the edge detection algorithm. The second array is called the kernel and is usually much smaller (but in the same dimension).

Each pixel of the image is added to its local neighbours, weighted by the kernel. This produces a new image. If the kernel is chosen wisely, we get all the edges found in the image.

Mathematically we can write the convolution as follows, with  $O$  the output image,  $I$  the input image and  $K$  the kernel:

$$O(i, j) = \sum_{k=1}^m \sum_{l=1}^n I(i+k-1, j+l-1)K(k, l) \quad (1)$$

### 1.1.2 Sobel

This algorithm performs a 2D spatial gradient measurement and finds regions of 'high spatial frequency' or edges. It uses two 3x3 kernels, one kernel is used for the vertical edges and the other for the horizontal edges in the image. These two kernels can be applied separately and afterwards combined together to find the absolute magnitude of the gradient.

The horizontal kernel:  $\begin{vmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{vmatrix}$  and the vertical kernel:  $\begin{vmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{vmatrix}$

### 1.1.3 Frei-Chen

The Frei-Chen algorithm also uses 3x3 kernels, but this time there are nine different convolution kernels. The four first matrices,  $G_1$ ,  $G_2$ ,  $G_3$ ,  $G_4$ , are used for edges, the next four are used for lines and the last one is used to compute averages.

$$\begin{aligned} G_1 &= \frac{1}{2\sqrt{2}} \begin{vmatrix} 1 & \sqrt{2} & 1 \\ 0 & 0 & 0 \\ -1 & -\sqrt{2} & -1 \end{vmatrix} & G_2 &= \frac{1}{2\sqrt{2}} \begin{vmatrix} 1 & 0 & -1 \\ \sqrt{2} & 0 & -\sqrt{2} \\ 1 & 0 & -1 \end{vmatrix} & G_3 &= \frac{1}{2\sqrt{2}} \begin{vmatrix} 0 & -1 & \sqrt{2} \\ 1 & 0 & -1 \\ -\sqrt{2} & 1 & 0 \end{vmatrix} \\ G_4 &= \frac{1}{2\sqrt{2}} \begin{vmatrix} \sqrt{2} & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & -\sqrt{2} \end{vmatrix} & G_5 &= \frac{1}{2} \begin{vmatrix} 0 & 1 & 0 \\ -1 & 0 & -1 \\ 0 & 1 & 0 \end{vmatrix} & G_6 &= \frac{1}{2} \begin{vmatrix} -1 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & -1 \end{vmatrix} \end{aligned}$$

$$G_7 = \frac{1}{6} \begin{vmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{vmatrix} \quad G_8 = \frac{1}{6} \begin{vmatrix} -2 & 1 & -2 \\ 1 & 4 & 1 \\ -2 & 1 & -2 \end{vmatrix} \quad G_9 = \frac{1}{3} \begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{vmatrix}$$

#### 1.1.4 Prewitt

This algorithm is very similar to the Sobel and Frei-Chen algorithms. Again, two kernels are used, one for the horizontal and one for the vertical edges. Afterwards, they are combined together to get all the edges in the image.

This time the kernels are considerably simpler:

$$\text{Horizontal filter} = \begin{vmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{vmatrix} \quad \text{Vertical filter} = \begin{vmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{vmatrix}$$

Because the kernels are simpler, the result is not so accurate when compared to the other algorithms.

#### 1.1.5 Roberts Cross

This algorithm uses even simpler kernels than Prewitt does. This time we use two 2x2 kernels. These kernels correspond to the edges running at 45° to the pixel grid, one for each of the two perpendicular orientations.

$$\text{Horizontal filter} = \begin{vmatrix} 1 & 0 \\ 0 & -1 \end{vmatrix} \quad \text{Vertical filter} = \begin{vmatrix} 0 & 1 \\ -1 & 0 \end{vmatrix}$$

#### 1.1.6 LoG

This algorithm combines two methods, the Gaussian filtering method<sup>1</sup> and the Laplacian method for edge detection<sup>2</sup>. Hence the name "Laplacian of Gaussian" (LoG). The edge points of an image are detected by finding the zero crossings of the 2<sup>nd</sup> derivative of the image intensity. Because the 2<sup>nd</sup> derivative is very sensitive to noise, which could give us bad results, the Gaussian filter is used to clear the noise from the image.

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<sup>1</sup>The Gaussian filter is used to blur images and remove noise and detail.

<sup>2</sup>This method highlights regions in the image of rapid intensity change, so it is useful for edge detection.

The R library `OpenImageR`<sup>3</sup> uses the following LoG mask.

$$\text{LoG mask} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{vmatrix}$$

### 1.1.7 Scharr

This algorithm is an extension of the Sobel algorithm. Although the Sobel kernels are very good, they do not have perfect rotational symmetry. This is what the Scharr kernels try to optimize.

The most frequently used kernels are the following:

$$\text{Horizontal filter} = \begin{vmatrix} 3 & 10 & 3 \\ 0 & 0 & 0 \\ -3 & -10 & -3 \end{vmatrix} \quad \text{Vertical filter} = \begin{vmatrix} 3 & 0 & -3 \\ 10 & 0 & -10 \\ 3 & 0 & -3 \end{vmatrix}$$

## 1.2 Color Analysis

Only edge detection algorithms are not going to be sufficient to get enough data from the image to form a musical interpretation. We will need some form of color analysis. This section proposes some algorithms and methods we can use to obtain information about the colors of the image.

### 1.2.1 RGB

This is the most common representation of color on a computer. Each pixel is described using three values, the amount of red (R), green (G) and blue (B) it has. Using these values we can count how many pixels in the image are dominantly red, green or blue. When we're going to translate the image data into musical patterns, we can match each color to another kind of music (happy, sad, etc...)

### 1.2.2 HSV

HSV, sometimes called HSB, is another representation of a pixel. This time we use the hue (H), the saturation (S) and the brightness or value (B or V) to

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<sup>3</sup><https://cran.r-project.org/web/packages/OpenImageR/OpenImageR.pdf>

describe the pixel. Where the RGB model consists of three values indicating the amounts of a certain color each pixel has, the HSV model consists of three independent components.

First we have the hue, which is basically the color. Here the color is represented using a circle with all the colors on it. So this means the value of this component is the degrees of the angle we have to make on the circle to get this color.

The saturation indicates the fullness of the color. This value is expressed in a percentage, with 0% a gray, flat color and 100% is a full, rich color.

The value or brightness indicates the lightness of the color and is also expressed in a percentage, 0% is black and 100% is white.

This representation will be used in combination with the RGB model in the translation into the musical patterns.

### **1.2.3 CMYK**

CMYK is another representation of color, based on the mixing of four colors, cyan (C), magenta (M), yellow (Y) and key (K, black). This model is used frequently with printing.

When combined, the data from the three models can be very accurate to use in the translation.

### **1.2.4 Black And White Balance**

During the image analysis we will convert the image to a gray scale image, so we can determine the amount of white and black in it. Using the RGB model, this is an easy process. Black in the RGB model is (0,0,0) and white is (255,255,255). So we can simply count the amount of pixels that are very close to those two values and we know the amount of black and white pixels in the image.

Analogous to this we can count every gray pixel in the image, by finding every pixel where the RGB values are exactly the same.