An introduction to Programming

Guido Klingbeil
Centre for Mathematical Biology
University of Oxford

Worksheet 9

Multidimensional Arrays and Image Processing
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In this exercise we cover two basic classes of operators commonly used in image processing: i) point operators, and ii) spatial operators. While point operators only consider the pixel itself, spatial operators take the surrounding pixels into account.

Point operators are used for image enhancement by modifying the image histogram. For example to increase the contrast of a low contrast image. You will implement two such operators: contrast stretching and histogram equalisation.

You will use spatial operators in two ways. Either to suppress noise by filtering with a median or Gaussian filter kernel, or to extract spatial features like edges from the image.

Since I would like you to work with both types of operators, the exercises are interleaved.

1. Download the file Lesson09.tar.bz2 from weblearn and decompress it into your home directory.

You will find all the necessary functions to read and write a NETPBM ASCII encoded greylevel image (P2) in the files image_p2.c (and its header file image_p2.h) and image_p2.pl, respectively. Furthermore, you will find short example programmes point_operators.c and point_operators.pl in the subdirectories point_operators/C and point_operators/perl, respectively. They read an image from file, compute the histogram, and convert the histogram into an image.
Compile and run the example files point_operators.c and point_operators.pl. The resulting programme reads an image from a file, computes its histogram, and writes the histogram to an image file.

2. For your language of choice, (compile and) run the example programme point_operators.c or point_operators.pl. If you are using C, compile gcc contrast_stretching.c pgm_routines.c -I. -lm
3. Open the example image with GIMP and compute its histogram. Make sure it looks the same as the one computed in step 2.
4. Implement a function that either stretches or equalises the histogram of an image and write the equalised histogram to a file. Compare it with the the equalised histogram provided in histogram_stretched.pgm and histogram_equalised.pgm. Why is the histogram no longer continous?
5. Implement a noise suppression filter. It is up to you if you want to implement an averaging, median, or Gaussian filter. You find an incomplete sketch of a filter function in the files sketch_of_spatial_filter.c and sketch_of_spatial_filter.pl.

The filter kernel of a 3x3 averaging filter is:

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}.$$

A possible 5x5 Gaussian filter kernel is:

$$\frac{1}{273}\begin{bmatrix}1 & 4 & 7 & 4 & 1\\ 4 & 16 & 26 & 16 & 4\\ 7 & 26 & 41 & 26 & 7\\ 4 & 16 & 26 & 16 & 4\\ 1 & 4 & 7 & 4 & 1\end{bmatrix}$$

6. The next exercises implement a simple gradient based edge detector. First the first step is to apply the in apply the vertical and horizontal Sobel edge detection operators. They compute the image gradient in vertical and horizontal direction.

   The horizontal Sobel operator:
   $$\begin{bmatrix}-1 & 0 & 1\\ -2 & 0 & 2\\ -1 & 0 & 1\end{bmatrix}$$

   The vertical Sobel operator:
   $$\begin{bmatrix}-1 & -2 & -1\\ 0 & 0 & 0\\ 1 & 2 & 1\end{bmatrix}$$

7. Compute the magnitude of the combined gradient and write the resulting edge map to an image. Please remember that the maximum allowed grey level is 255.
8. Implement thresholding. Thresholding is a simple technique to distinguish pixels belonging to an edge from the rest. Classify the pixels into edge / non-edge points by applying a threshold in terms of percent of the maximum gradient magnitude observed.
9. As you can see, thresholding is not the most efficient way to distinguish an edge point from other non-edge points. Especially when the image is noisy continuous edges may be broken into several disconnected segments. Another technique is edge tracing with hysteresis. The idea is simple. You define two thresholds, a high and a low one. You start tracing an edge at a point exceeding the high threshold. You trace the edge until you reach a point below the low threshold. Try to implement this technique.

End of worksheet 9.