SKELETONS IN THE CUPBOARD – FIRST STEPS IN IMAGE ANALYSIS

Introduction

This project explores algorithms for extracting the skeleton of an image – the essential underlying pattern of lines, loops, etc. which can then be used as a foundation on which to build schemes for recognising characters. Examples are taken from *Algorithms for Image Processing and Computer Vision* by J.R. Parker, and use the files `test2a.pbm`, `tsp.pbm`, `5.pbm`, `8.pbm`, `b.pbm`, `h.pbm`, `test3.pbm`, `v.pbm`, `x.pbm`.

Iterative Morphological Methods

The basic aim of these methods is to thin a figure to a single line of pixels. This requires a set of rules defining which pixels can be removed: the rules are applied iteratively until there is no further change from one iteration to the next. The Stentiford algorithm (F.W.M. Stentiford and R.G. Mortimer, Some new heuristics for thinning binary handprinted characters for OCR, *IEEE Transactions of Systems, Man and Cybernetics* **SMC-13**, 81-84, 1983) uses 3×3 templates, where a match of the template to the image means delete (set to white) the centre pixel. The algorithm is

1. find a pixel (i, j) whose neighbourhood matches template M1;
2. if (i, j) is not an endpoint (i.e. if it has more than one neighbour out of a possible eight) and has connectivity number = 1, mark it for deletion;
3. repeat steps 1 and 2, scanning left to right, top to bottom (to remove upper edge pixels);
4. repeat 1-3 for template M2, scanning bottom to top, left to right;
5. repeat 1-3 for template M3, scanning right to left, bottom to top;
6. repeat 1-3 for template M4, scanning top to bottom, right to left.
7. if any pixels have been marked for deletion, delete them;
8. if any pixels have been deleted, repeat from step 1, otherwise stop.

In the templates, black or white circles much match image and background respectively, whereas the empty squares may be of either colour.

M1 M2 M3 M4

The connectivity number aims to describe how many parts of an object a pixel might connect. A suitable definition is

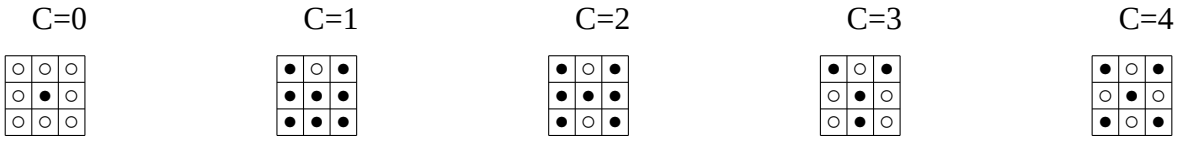
$$C_n = \sum_{k=1,3,5,7} \left(p_k - p_k p_{k+1} p_{k+2}\right),$$

where p_k denotes the value of pixel k (1 for white, background; 0 for black, object), and the pixels are numbered around the central point (0)

4	3	2
5	0	1
6	7	8

in a cyclic fashion (point k = point $k - 8$ if $k > 8$.

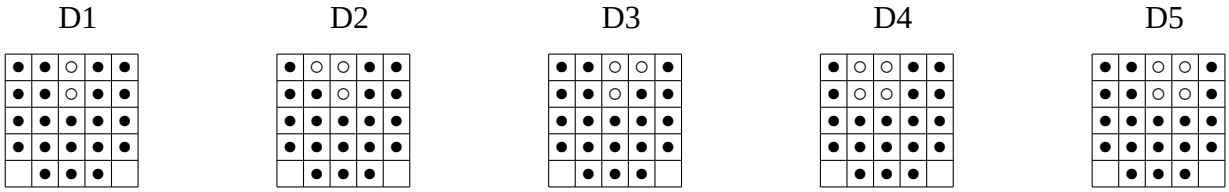
Some examples of connectivities are:



Try this scheme on the sample files, and observe the artefacts called *necking*, *tailing* and *spurious projections*.

Stentiford suggests two preprocessing steps. To remove projections, pass over all the pixels and delete all having two or fewer image point (black) neighbours and a connectivity number less than two.

To treat necking, emphasise any acute angles using the following templates. If a template matches the image, the central point is deleted and another iteration is undertaken using just the first three templates of each type. The series D1 to D5 is shown below – U1 to U5 are the same, but inverted.



Zhang-Suen Algorithm

This algorithm is broken into two sub-iterations, as follows: first, mark a pixel (i, j) for deletion if *all* the following are true:

1. its connectivity number is 1;

2. it has at least two and no more than six black neighbours;

3. at least one of $(i-1, j)$, $(i, j+1)$ and $(i+1, j)$ are background (white);

4. at least one of $(i, j+1)$, $(i+1, j)$ and $(i, j-1)$ are background;

delete all the marked pixels, and then marka pixel (i, j) for deletion if *all* the following are true:

1. its connectivity number is 1;

2. it has at least two and no more than six black neighbours;

3. at least one of $(i, j+1)$, $(i-1, j)$ and $(i, j-1)$ are background (white);

4. at least one of $(i-1, j)$, $(i+1, j)$ and $(i, j-1)$ are background.

The algorithm can be further improved by *staircase removal*. Also, one can combine the preprocessing steps of the Stentiford scheme with this algorithm.

Force-Based Thinning

To be added if time.

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