Image Enhancement by Fast Distance Transform

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Abstract. A new and fast non-Euclidean distance transform is presented which belongs to a class of raster scanning methods. The proposed algorithm is about 30% faster than other similar techniques and shows good results when applying to solve an image enhancement task.

1. INTRODUCTION

The distance transform (DT) is a method to convert a binary image to halftone one. As a result, every pixel on the halftone image receives a value equal to distance to some feature pixel set. Here, we will only consider the raster-scanning non-Euclidean sequential DTs which are simpler to realize than other DTs.

Standard algorithms of this type require 2 scans of a whole image to perform the DT. Aim of this paper is to develop a method analyzing only once as many image pixels as possible. The fast DTs with low memory requirements are necessary for different real applications. One example can be an image enhancement where one need reconstruct an initial object shape from disconnected components resulting from distortions (binarization effects, low print quality and so on).

2. DEFINITIONS

Suppose that the original image is binary one of size NxN pixels. It consists of feature (or F) and non-feature (or NF) pixels. F-pixels are initialized by zeroes, while NF-pixels obtain the values M (M - large positive integer). Each continuous interval of F-pixels in the ith image row is coded by two values: xl_i and xr_i corresponding to x-coordinates of its ends. Variable xf_i denotes the x-coordinate of the first processed pixel in the ith row.

3. NOVELTY OF APPROACH

Modifications of the standard DT algorithm are concerned with:

1. Start of the forward DT scan.
2. Implementation of the forward DT scan.
3. Start of the backward DT scan.
4. Usage of the interval coding of F-pixels in addition to the initial raster image.

It is worth to say that an interval representation does not take much memory space. Usually it requires about 10-20% space necessary for the raster image. Due to this coding, runtime of the DT decreases as F-pixels are not analyzed.

4. MODIFICATION DESCRIPTION

Due to limitations of paper length, the modifications of the DT will be briefly given. Detailed algorithm description can be found in [1,2]. Here and further we will assume that the DT is performed for NF-pixels.

4.1. Start of the forward scan

According to the standard DT algorithms, a processing starts from the first image row. However, it is not necessary because it is well known that the NF-pixels above the image row, where the first intervals of the F-pixels are, do not obtain their final values within the forward scan. **A modification of this step is that a processing starts from NF-pixel located behind right end of the first interval.**

4.2. Implementation of the forward scan

A main purpose at this stage is to decrease amount of processed pixels in every image row. To do so, it is important to know a position (xf_i) of the first pixel to be analyzed in each row. It was found from analysis of possible situations that the following rules occur (xl_i is set to *-1, if there are no F-pixels in the ith row):*

1. if (xl_{i-1}=-1 and xl_i=-1) then xf_i=xf_{i-1}-1.
2. if ((xl_{i-1}=-1 and xl_i>0) or (xl_{i-1}>0 and xl_i>0 and xl_{i-1}>xl_i)) if (xf_{i-1}>xl_i) then xf_i=xr_i+1, otherwise xf_i=xf_{i-1}-1.

3. if (($xl_{i-1}>0$ and $xl_i=-1$) or ($xl_{i-1}>0$ and $xl_i>0$ and $xl_{i-1}\leq xl_i$)) if ($xf_{i-1}>xl_{i-1}$) then $xf_i=xl_{i-1}-1$, otherwise $xf_i=xf_{i-1}-1$,

4. if $xf_i=0$ then $xf_i=-1$.

As a result, in every row the DT is only performed for NF-pixels by starting from $x=xf_i$.

4.3. Start of the backward scan

After the forward scan some pixels already obtained their values which are not further updated within the backward scan. These pixels are in a region below the last row containing F-pixels. However, some correction is necessary for the pixel values in this region.

Here, a distance value propagation direction is horizontal because there are no other F-pixels below. Therefore, it is sufficient to analyze the values of two adjacent pixels at positions (x-1,y) and (x,y) to correct the distance values. A correction rule is simple because of a horizontal value propagation. According to properties of the DT, the values of the pixels (x-1,y) and (x,y) cannot differ by a value greater than a "unit" horizontal distance in given metric (for example, for 3-4 weighted DT this distance is 3). If it is not so, correction is necessary. A correction procedure is given in C-like code in Fig.1. **The backward DT scan starts from the row imax after this correction.**

5. IMAGE ENHANCEMENT BY NEW DT

Enhancement is necessary to improve an image quality before its segmentation and recognition. One of image distortions which can be eliminated by this operation is an object separation into several disconnected blobs.

An image enhancement using the DT algorithm described in the previous section consists in the following.

1. Initialize an image as given in section 2. Perform the new DT for NF-pixels by updating the pixel values only if they are greater than a threshold Th. As a result, the obtained image holds the values 0 to Th and equal to M (Th<<M).

2. Calculate the standard DT for pixels with values 0 to Th.

3. Extract from the resulting image all pixels whose values are greater than Th+M. These pixels correspond to the desired reconstructed object.

6. RESULTS

Images of text symbols were taken as test examples. To calculate a distance, city block, chessboard and 3-4 weighted metrics were used. Aim was to compare an original image and one after enhancement. Results were good for 3-4 weighted DT, while they were poor for other DTs. In Fig.2, in every triplet (from left to right), an initial undistorted symbol, distorted and reconstructed ones are shown, respectively. Enhancement results obtained by the standard and our methods fully coincide. This means that introduced modifications of the standard DT are correct. However, our method is about 30% faster than other DTs of this type.

7. ACKNOWLEDGMENT

This work has been supported in part by the grant (N# INTAS-94-0459).

8. REFERENCES

1. Okun O., Ablameyko S., Modified distance transform with raster scanning value propagation // SPIE Proc. on Vision Geometry V, Vol.2826, Denver, USA, 1996.

2. Okun O., *Document Image Segmentation by Distance Transforms*, Ph.D. theses (in Russian), Minsk, 150 pages, 1996.

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/* imax - image row number where the last intervals of F-pixels are */
/* n - the number of intervals in this row */
/* xll_i - x-coordinate of the left end of the ith interval in this row */
/* N - the number of image rows */
/* xc_i, xc_i+1 - x-coordinates of the ith correction interval */
/* hd - unit horizontal distance in given metric */
/* a_x,y - value of the pixel (x,y) */

i1=imax+xl_imax; if(i1≥N-1) i1=N-2;
for(i=0;i<n;i++) xc_i=imax+xll_i-i1;
for(y=i1;y<imax;y--)                {
  for(i=0;i<n;i++)
  for(x=xc_i+1; x>xc_i;x--)
  /* Correction */
  if(a_x-1,y-a_x,y>hd) a_x-1,y=a_x,y+hd;
  for(i=0;i<n;i++) xc_i++;           }
```

Fig. 1 Correction rule.

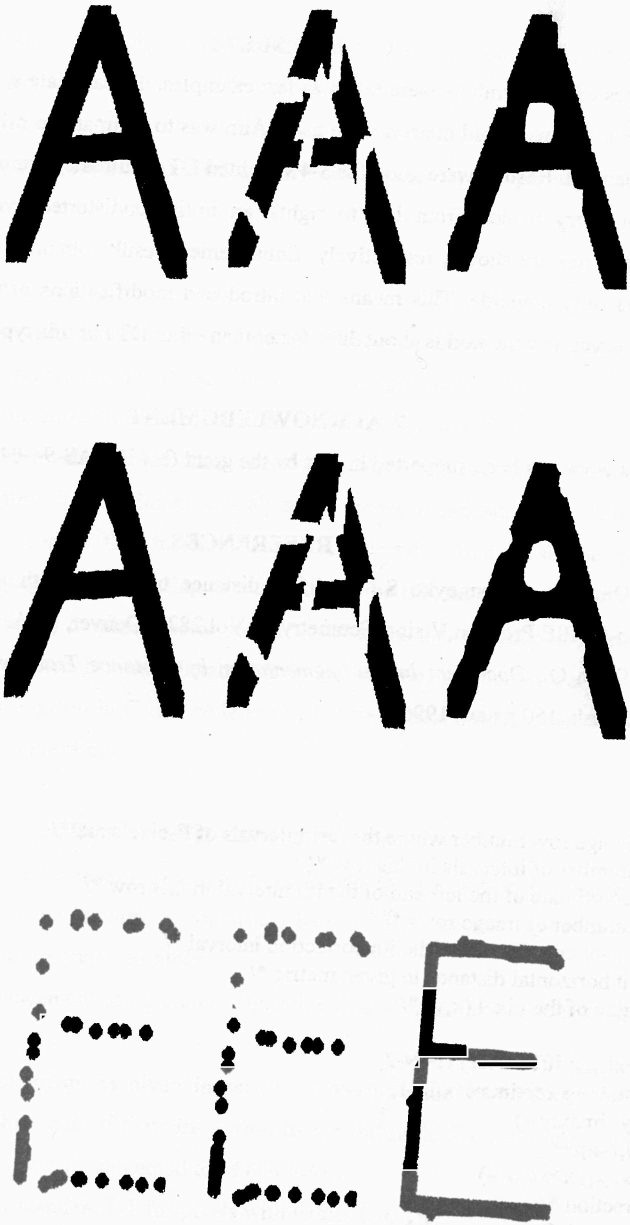

Fig.2. Initial image, distorted one and enhancement result.