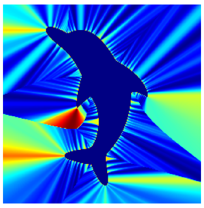
Sub-pixel Euclidean distance transform

Robin Strand
Centre for Image Analysis
Swedish University of Agricultural Sciences
Uppsala University

Reference



Pattern Recognition Letters 32 (2011) 252–257
Contents lists available at ScienceDirect
Pattern Recognition Letters
journal homepage: www.elsevier.com/locate/patrec

Anti-aliased Euclidean distance transform

Stefan Gustavson [a,*], Robin Strand [b,**]
[a] Media and Information Technology, Linköping University, Sweden
[b] Centre for Image Analysis, Uppsala University, Sweden

ARTICLE INFO
Article history:
Received 8 July 2009
Available online 7 September 2010
Communicated by T.K. Ho

Keywords:
Distance transform
Vector propagation
Euclidean metric
Sub-pixel accuracy

ABSTRACT
We present a modified distance measure for use with distance transforms of anti-aliased, area sampled grayscale images of arbitrary binary contours. The modified measure can be used in any vector-propagation Euclidean distance transform. Our test implementation in the traditional SSED8 algorithm shows a considerable improvement in accuracy and homogeneity of the distance field compared to a traditional binary image transform. At the expense of a 10× slowdown for a particular image resolution, we achieve an accuracy comparable to a binary transform on a supersampled image with 16 × 16 higher resolution, which would require 256 times more computations and memory.

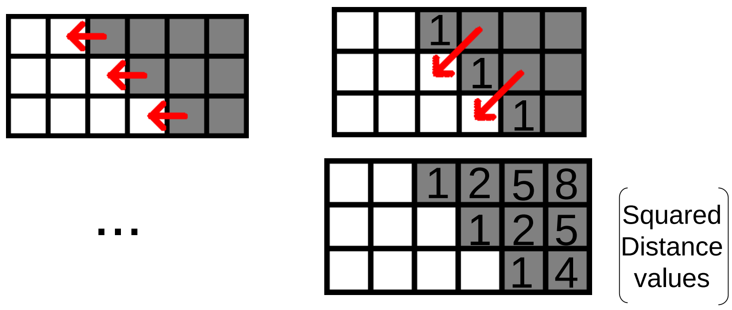
Assumptions

- Binary objects
- Smooth contour
- Pixel coverage digitization

Real world digital imaging: Finite-area sensor element.
We don't consider the point spread function here.

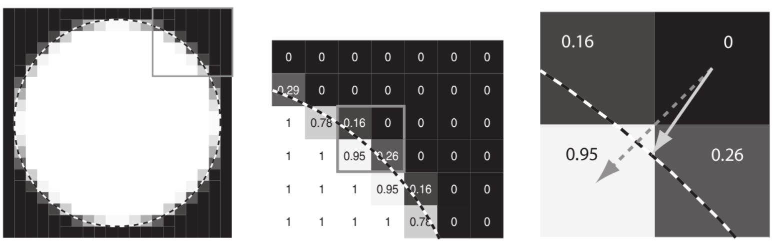
Vector propagation Distance Transform

- (Image Analysis 2)



Sub-pixel vector propagation

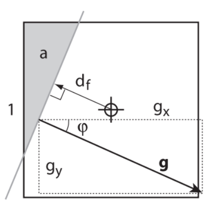
- Pixel coverage digitization



(a) (b) (c)

Sub-pixel vector propagation

- Using pixel coverage to estimate the border position
  - Linear ramp
  - By the geometry of the pixel (the border direction and the area coverage gives the relation between a and d_f)

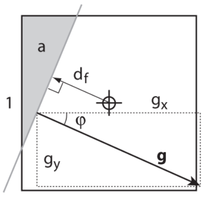


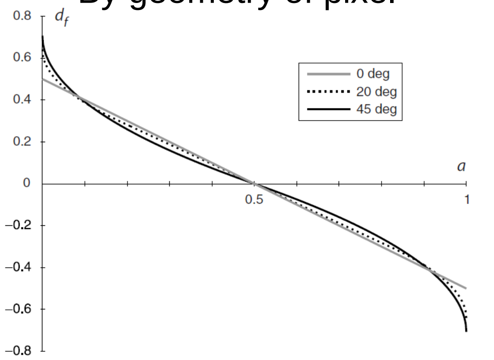
Relation between a and d_f

Linear ramp

$$d_f = 0.5 - a$$

By geometry of pixel

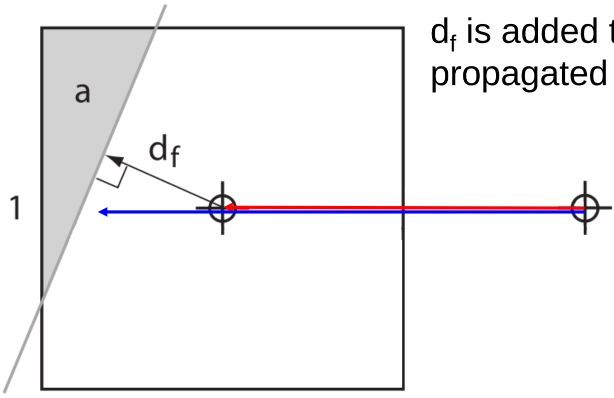




Algorithm 1

- Border points have pixel coverage, a, values in]0,1[
- d_f=05-a
- Pixel coverage gives the position of the border.

Algorithm 1

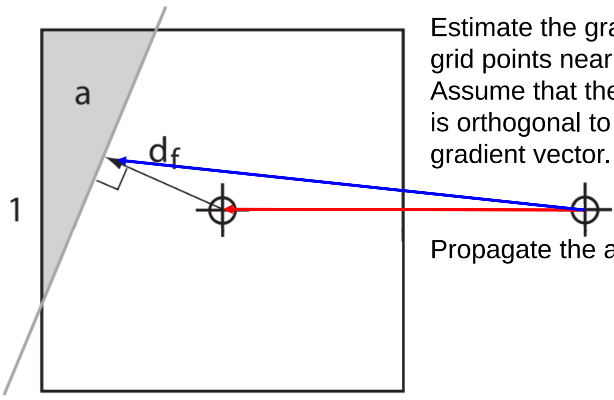


d_f is added to the propagated vector.

Algorithm 2

- Border points have pixel coverage values in]0,1[
- A gradient approximation is computed at each border point to get a local border direction. (OK if boundary is smooth.)
- Pixel coverage and direction gives the position of the border.

Algorithm 2



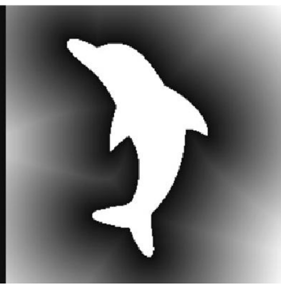
Estimate the gradient at grid points near the edge. Assume that the edge is orthogonal to the gradient vector.

Propagate the added vectors.

Experiments

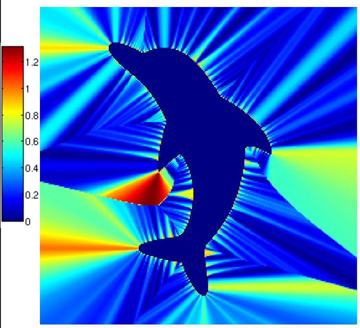
Test image

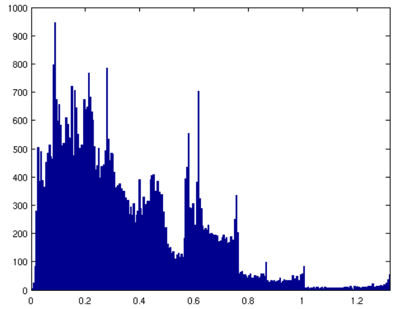
Area sample



Distance transform

Experiments

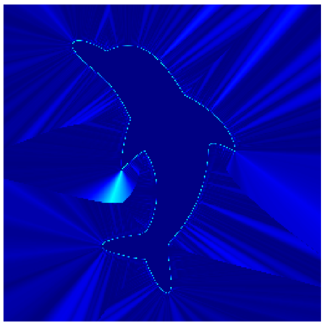


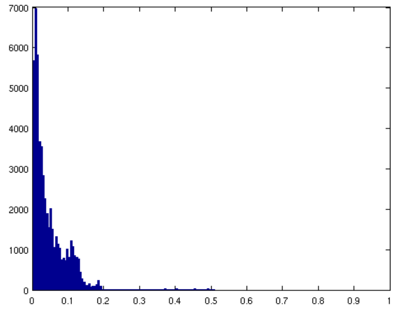


Original algorithm

Distribution of errors

Experiments

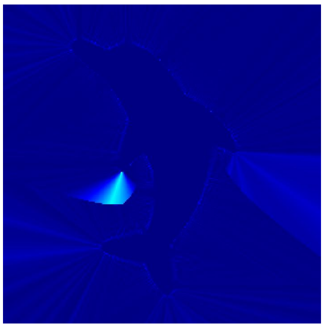


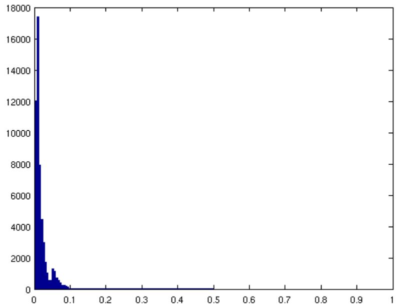


Sub-pixel algorithm
Linear ramp approximation

Distribution of errors

Experiments





Sub-pixel algorithm

Distribution of errors

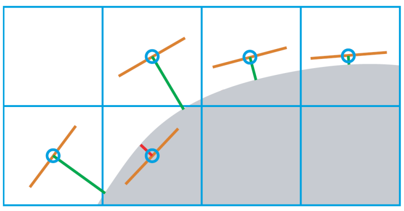
Discussion

- Result comparable to using the original algorithm on a 16x16 up-sampled image.
- About ten times slower. Approximations, look-up tables etc. makes it faster.
- Applications: When the assumptions are met and a smooth distance field is needed. Registration, set distance, smooth skeleton, …

Demo…

Computer graphics application. Smooth border from binary images. Zoom-in.

Gradient + distance value is interpolated to get the border of the object.



Distance transform obtained as before.

Extensions

- Higher dimensions
- Other sampling geometries
- Optimized algorithms (look-up tables, …)
- Useful in your research project?