Sub-pixel Euclidean distance transform

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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

Sub-pixel vector propagation
- Using pixel coverage to estimate the border position
  - Linear ramp
  - By the geometry of the pixel (the area coverage gives the relation between a and d)

Reference
Relation between $a$ and $d_f$

**Linear ramp**

$d_f = 0.5 - a$

By geometry of pixel

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**Algorithm 1**

- Border points have pixel coverage, $a$, values in $]0,1[$
- $d_f = 0.5 - a$
- Pixel coverage gives the position of the border.

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**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.

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**Experiments**

- Test image
- Area sample
- Distance transform
Experiments

Original algorithm

Distribution of errors

Sub-pixel algorithm

Linear ramp approximation

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?