Fast Level Lines Transform algorithm

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About Olena:

- Generic image processing library
- Developed at the LRDE [ole]
- Latest release, April 2004
The FLLT algorithm

Roughly

- Introduced by Pascal Monasse and Frédéric Guichard in [MG98]
- Image segmentation algorithm
- Contrast invariant image representation
- *Should be faster than existing algorithms*

Figure: Image, the extracted contours, the segmentation
Contrast invariance?

- Contrast is hardware dependant
- Grey level quantization process
- Brightness

A limited greylevel space to represent all the magic of our world?

Figure: A greylevel scale: from 0 (black) to 255 (white)
Outline

1. Concept
2. Theory
3. The algorithm
A special image representation

Figure: Original image

Figure: Corresponding inclusion tree

Fast Level Lines Transform algorithm
Connected components

**Connected operators** \( \psi \)

- \( \forall y \in \mathcal{N}(x), f(x) = f(y) \Rightarrow \psi(f)(x) = \psi(f)(y) \)
- Input flat zones are included into output flat zones
- Preserve object contours

**Leveling**

Subclass of connected operators

- \( \forall y \in \mathcal{N}(x), f(x) < f(y) \Rightarrow \psi(f)(x) \leq \psi(f)(y) \)
- Preserve local spatial ordering of the image
Upper level set $\chi_\lambda$ and lower level set $\chi_\mu$

$$\chi_\lambda = \{ x \in \mathbb{R}^2, u(x) \geq \lambda \}$$
$$\chi_\mu = \{ x \in \mathbb{R}^2, u(x) \leq \mu \}$$

The family of $\chi_\lambda$ (or $\chi_\mu$) is sufficient to rebuild the image:

$$u(x) = \sup\{ \lambda / x \in \chi_\lambda \} = \inf\{ \mu / x \in \chi_\mu \}$$

Consequence

$$\forall \lambda \leq \mu, \chi_\lambda \supset \chi_\mu, \chi_\lambda \subset \chi_\mu$$

Inclusion of the level sets implies a tree structure

Moreover these operators are contrast invariant
Jordan theorem

- $C$ is a closed curve in the plane $\mathbb{R}^2$
- Space separated in 2 connected components, *in* and *out*
- This is applied to $\mathbb{Z}^2$, the 2D image domain
Jordan theorem in 2D image space

- $H$ is no longer a closed curve in the plane $\mathbb{Z}^2$
- Brings up problems to detect interior and exterior
- We need to use different connexity for interior and exterior

**Figure:** 4-connexity

**Figure:** 8-connexity
**Inputs**

- Image to process

**Outputs**

- A tree of ordered shapes expressing the “brighter than” relation
- An image expressing the smallest shape containing a pixel

**Principle**

- Build the upper level sets and lower level sets trees of connected components
- Find the correspondance in both trees of “holes”
- Merge the trees
Building of the level sets trees

**Principle of lower level set tree construction**

1. Image scanning
   search for a not tagged local minimum
2. Create a new “region” with this local minimum
3. Examine the neighbors and proceed with a region growing
4. Continue until borders of region are reached

Return to step 1 until end of image

Apply the same algorithm for upper level set building (searching for local maximums)
Example of lower level tree building

Processed image: Using the set of points sorted by greylevel

Stages:
Example of lower level tree building

Processed image: The first minimum not tagged is processed

Stages:
Example of lower level tree building

Processed image: Region growing

Stages:
Example of lower level tree building

Processed image: The next not tagged minimum is processed

Stages:
Example of lower level tree building

Processed image:  

Region growing

Stages:

level = 0
Example of lower level tree building

Processed image: The next not tagged minimum is processed

Stages:
Example of lower level tree building

Processed image: The entire image has been processed

Stages:
Example of lower level tree building

Processed image:

Lower level tree complete!

Stages:
Final stage: merging the trees

Nothing to do if no shape is “pierced”
Otherwise we apply some rules to merge the branches

The processed image was:
Final stage: merging the trees

Nothing to do if no shape is “pierced”
Otherwise we apply some rules to merge the branches

The processed image was:
Applications

Fast Level Lines Transform algorithm
Applications
Work relevance

- Understand this algorithm
- Prepare an implementation
- Finally, use FLLT in Olena
Bibliography I

C. Ballester, V. Caselles, and P. Monasse.
Preprint CMLA.

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Digital topology lecture.

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