Image Processing
Project Presentation

Active Contours Without Edges

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Outline

Introduction

Problem

Edge detection is the problem of finding lines separating homogeneous regions.[1]

Figure 1: Edge detection example

The model should

- Find global contours which best reproduce the apparent contours in the image
- Be able to extract smooth shapes: we get regular contours.
- Respect some singularities: angles, sharp corners ..
- Respect the robustness of the algorithms: stable, convergent with a minimum set of parameters

State of the art

STATE OF THE ART

Several methods were introduced in the article, the most relevant for the next step are :

THE CLASSICAL METHOD OF SNAKES

The main idea is to formalize the problem as an energy minimization one

- We first define the internal energy $E_{\text{int}} = \int_0^1 \left(\alpha \left|v'(t)\right|^2 + \beta \left|v''(t)\right|^2\right) dt$ [3]
- The external one as $E_{\text{ext}} = -\lambda \int_0^1 |\nabla I(v(t))| dt$
- We minimize the sum : $E = E_{\text{int}} + E_{\text{ext}}$

GEOMETRIC PDE MODEL BASED ON THE MEAN CURVATURE

- The following equation describes the motion of the level sets of the function u,
$\frac{\partial u}{\partial t} = |\nabla u| \operatorname{div}\left(\frac{\nabla u}{|\nabla u|}\right) \quad (t, x) \in [0, \infty[\times \mathbb{R}^2$
- We add a term and multiply by g(x)
$\frac{\partial u}{\partial t} = g(x)|\nabla u| \left(\operatorname{div}\left(\frac{\nabla u}{|\nabla u|}\right) + v\right) \quad (r, x) \in [0, \infty[\times \mathbb{R}^2$
- $g(x) = \frac{1}{1+(\nabla G_\sigma * g_0)^2}$

The limitations of the models

Models limitations

Snake Model Limitations

- Over-smooth the boundary
- Not able to follow topological changes of objects
- External energy: snake does not really “see” object boundaries in the image unless it gets very close to it

Figure 2: Snake model is not able to detect contours due the noise

Geometric PDE model Limitations

- The model can detect only objects with edges defined by gradient.
- The discretization of the problem is made on a fixed rectangular grid
- The method still suffers from boundary leaking for complex structures.

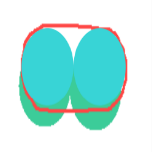

Figure 3: Morphological changes are not detected

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Active Contours without Edges Model

The model and the Algorithm

We introduce a fitting term "without edges" :

$$F_1(C) + F_2(C) = \int_{inside(C)} |u_0(x,y) - c_1|^2 \, dxdy + \int_{\text{outside } (C)} |u_0(x,y) - c_2|^2 \, dxdy \tag{1}$$

We can formulate an energy functional to minimize :

$$F(c_1, c_2, C) = \mu \cdot \text{Length}(C) + \nu \cdot \text{Area}(inside(C)) + \lambda_1 F_1(C) + \lambda_2 F_2(C) \tag{2}$$

We deduce the Euler-Lagrange equation of the level set function $\phi(x,y)$:

$$\frac{\partial \phi}{\partial t} = \delta_\varepsilon(\phi)\left[\mu \operatorname{div}\left(\frac{\nabla \phi}{|\nabla \phi|}\right) - \nu - \lambda_1 (u_0 - c_1)^2 + \lambda_2 (u_0 - c_2)^2\right] = 0 \text{ in } (0, \infty) \times \Omega \tag{3}$$

[2]

Proposed Algorithm

- Initialize ϕ^0 by $\phi_0, n = 0$.
- Compute c_1 and c_2 as $c_1(\phi) = \text{mean}\,(u_0)$ in $\phi \geq 0$ and $c_2(\phi) = \text{mean}\,(u_0)$ in $\phi < 0$
- Solve the PDE in ϕ from (3), to obtain ϕ^{n+1}.
- Reinitialize ϕ locally to the signed distance function to the curve.
- Check whether the solution is stationary. If not, $n = n + 1$ and repeat.

Implementation in Python

IMPLEMENTATION IN PYTHON

IMPLEMENTED FUNCTIONS

- **acwe**(Img, phi0, max_iter, time_step, mu, v, lambda1, lambda2, epsilon) : Function that implements the Vese Chan algorithm defined above.
- **initialize**(width, height, x_center, y_center, radius): Function that defines an initial contour
- **curvature_central**(phi) : Function that calculates the divergence in equation 3
- **gradient**(f): Function that computes and returns the gradient
- **NeumannBoundCond**(f) : Transformation of the function f to satisfy the Neumann boundary condition
- **show_curve_and_phi**(fig, Img, phi, color) : Function that displays the contour on the input image
- **main function** : where will read the bitmap image, initialise the contour and call the **acwe** function which calls the other functions

Test of the method on a database of images

Test of the method on a set of images

The images used for the test are the ones from the laboratory.

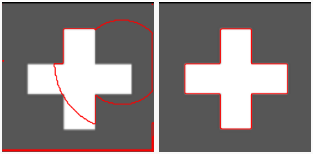

Figure 4: Simplistic example for the detection of the contours of the Swiss flag, the first image is the one with the beginning contour and the second is the image after the end of the algorithm

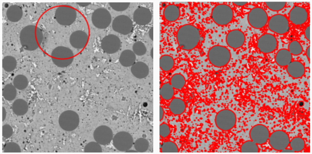

Figure 5: The Vese and Chan algorithm applied to a ceramic image that is dense in contours

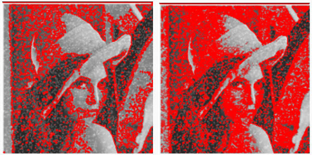

Figure 6: Vese and Chan Algorithm applied a noisy image with different ν, 0.2 on the left and 0 on the right

Figure 7: Vese and Chan algorithm applied to Lena image

Conclusion about the model and Perspectives

Conclusion about the model

Advantages

- The model permits to detect objects without sharp edges
- It detects cognitive contours
- The model is robust to noise and it needs not a pre-smoothing process
- The initial contour can be anywhere on the image and it does not need to surround the object to be detected

Disadvantages

- The algorithm is sometimes quite slow, especially when dealing with large images. It can pose a problem for real time applications, such as video sequences.

Perspectives and improvements

- There are some papers which suggest refinements to this algorithm, especially for the time-consuming computation of the PDE solution. These methods use values that were already computed, in order to decrease the computing time of the next values. [4]

BIBLIOGRAPHY

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