EE4902 Part 2 Assignment 3

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# Investigate the role of sigma in Gaussian smoothing, influence of initialization, effects of alpha and beta in the energy function, ability to deal with corner points.

## Role of Sigma in Gaussian Smoothing

Gaussian Filter is a low pass filter, which essential blurs or smooths the image. The role of sigma in the Gaussian filter is to control the variation around its mean value. So as the sigma becomes larger the more variance allowed around mean and as the sigma becomes smaller the less variance allowed around mean. The higher the value of sigma, the more blurring occurs.

Table ‑ Effect of Gaussian smoothing on snake

|  |  |  |
| --- | --- | --- |
| Blurred Image | Standard Potential Field | After 40 iterations |
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|  |  |  |
|  |  |  |

The value of sigma also affects the standard potential field. High sigma increases the speed of deformation. As seen, with increasing sigma, the external force exerted has a larger area of influence. As such, the force exerted can pull the green contour quickly. The tradeoff, however, is that the original image becomes blurred. As a result, the snake converges to a shape that is Gaussian blurred. Critical details about the image are lost, such as sharp corners or fine detail. Generally, the GVF is preferable for increasing the speed of deformation because the GVF does not blur the image itself. However, sometimes a Gaussian blur may be used in smoothing out noise. On the other hand, the GVF is unable to smooth out noise, so it will propagate fields out of the noisy part of the image as well, which is not desirable.

## Influence of initialization

The initial position of the curve affects whether it converges to a solution or not. To optimize the performance of the snake, the approximate shape and size of the image should be known.

When the initial curve is initialized too far away from the original image, it takes significantly more iterations to converge to a solution. The speed of convergence is also smaller. This is because when the initial curve is far away from the original image, the external force applied to ‘shrink’ the initial curve is very small. If the initial curve is too far away, the external force applied to shrink the initial curve is so small that the curve may never converge at all.

Table ‑ Effect of initialization on snake

|  |  |  |
| --- | --- | --- |
| Radius | Initialization | 40 Iterations |
| 0.45 |  |  |
| 0.55 |  |  |
| 0.65 |  |  |
| 0.75 |  |  |

The above results were obtained at , and different positions of initialization were created to demonstrate the effect that initialization has on whether the snake converges. In the following images, so that the snake’s ability to converge is only affected by the external field.

When radius was 0.45 every part of the snake was under the influence of the SVF. As such, after 40 iterations, the snake had converged almost fully conforming to the shape of the image contour. However, when the radius was 0.55 and 0.65, only certain parts of the snake were under the influence of the SVF. Only the portions of the snake inside of the SVF could converge. When the radius was 0.75, the snake was not under the influence of the SVF, and hence was unable to converge at all.

## Effects of alpha beta in the energy function

The snake is an active contour model that performs the task of image segmentation. Its objective is to divide the image into meaningful regions, such as objects, background and outline. A snake is an active contour model and it represents an object as a parametric curve. An energy function is associated with the curve. With repeated iterations, the snake aims to minimize the energy associated with the curve. The total energy is a function of both external energy (produced by the image) and internal energy (produced by the snake).

### Elastic Potential Energy

The curve is treated as an elastic rubber band possessing elastic potential energy

The weight α (s) allows us to control elastic energy along different parts of contour. It is set as a constant independent of s for many applications. It discourages stretching by introducing tension. It is responsible for shrinking the contour. Having α allows the snake to shrink even without the presence of an external field. When is larger, the snake shrinks faster. When is zero, the snake does not have the internal energy to shrink at all. The following snake and image were set such that the snake lies outside of the external field, with and at varying levels of , and number of iterations is 40. The red parts highlight the amount of deformation that has taken place. The series of simulations shows that with larger , the snake shrinks further.

Table ‑ Effect of on snake

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| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

### Bending Energy

The snake is also considered to behave like a thin metal plate giving rise to bending energy.

Bending energy tries to smooth out the shape contour. Bending energy is minimum for a circle. The ability of the snake to deal with corner points is affected by its internal bending energy. High bending energy eliminates corners in the snake, so the snake tends to converge into a circle. This is not to be confused with the effect of sigma in eliminating corners in the original image.

Table ‑ Effect of on snake

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| --- | --- | --- |
|  |  |  |
|  |  |  |

## Ability to deal with corner points

The images show the resulting snake after 40 iterations of a square contour with . The square contour is drawn such that the external force has no effect on the snake. As shown, with increasing beta, the snake converges to a circular shape faster. However, increasing beta lowers the ability of the snake to deal with corner points as the snake tends to become rounded at the corners. The following figures show that the snake with a higher beta has a more rounded shape at the corners.

Table ‑ Effect of β on ability to deal with corner points

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| --- | --- |
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|  |  |

# Investigate the performance of the GVF method.

What the GVF method does is that it iteratively expands the field lines of the standard vector field. With more field lines, the snake will converge much faster. The following table illustrates the effect of increasing iterations on the size of the GVF.

Table ‑ Effect of number of iterations on size of GVF

|  |  |  |
| --- | --- | --- |
| 1 iteration | 2 iterations | 10 iterations |
|  |  |  |

To investigate the performance of the GVF verses the SVF, a series of snakes were initialized with and and . On the GVF, the number of iterations is 80, so the GVF wraps around the entire snake. As illustrated below, the GVF extends the external field, allowing the snake to converge faster than in the SVF.

Table ‑ Comparison between SVF and GVF when snake is small

|  |  |  |
| --- | --- | --- |
| R = 0.45 | Initial | 40 Iterations |
| SVF |  |  |
| GVF method |  |  |

When the initialization position is not set to be within the field, the SVF typically suffers from the snake being unable to converge. The GVF overcomes this problem by extending the size of the field, such that the snake will be able to converge, as illustrated below.

Table ‑ Comparison between SVF and GVF when snake is large

|  |  |  |
| --- | --- | --- |
| R = 0.75 | SVF method | GVF method |
| Initial |  |  |
| After 40 iterations |  |  |

### Concave Boundary Problem

The GVF method also overcomes the problems of the concave boundary as the field is able to pull the snake into the boundary cavity. The traditional Standard Vector Field method is unable to pull the snake into the boundary cavity. If we examine the field lines, we see from Figure 1 that there is no downward component of the field line. In the GVF, the extended fields exert a downward component of the force

|  |  |
| --- | --- |
| Figure 1 SVF Concave boundary | Figure 2 GVF Concave Boundary |

# Experiment with rectangular (or other) shapes using binary images to perform your analysis.

Circular shapes were found to perform the best in most cases, but in general, a snake whose shape closely resembles the image works best. If the shape is odd and the edges are sharp such that they do not fit well with the original image, the snake does not deform efficiently. However, in the presence of a strong external field and with high enough and , this can be overcome. ­

Take for instance, snakes with the following shapes with protruding edges, where the snake is not well conformed to the image. The snake deforms efficiently so long as the snake is well fitted inside of the external field, but otherwise does not. Parts of the snake that lie on the field deform faster. Though it was initially mentioned that circular snakes tend to work best, the last circular snake in the following table hardly deformed. This is because there is hardly any force exerted by the external field. When put inside of a large GVF, all snake shapes performed equally, in that they were able to fit the image contour well. Hence, there is no ‘best’ shape of the snake. It all depends on the image.

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| --- | --- | --- |
| Shape | After 40 iterations inside a SVF | After 40 iterations inside a GVF |
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|  |  |  |
|  |  |  |
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# Investigate the feasibility of initializing completely inside the object and expanding the snake outwards using only the gradient (external energy). When the snake stabilizes, you can introduce both the internal energy and external energy

can only shrink the snake. In this case, the snake was initialized inside of the shape, such that the external force is not exerted onto the snake. The result is that the snake is shrunk, and is unable to conform to the shape.

|  |  |  |
| --- | --- | --- |
|  | Before | After 40 iterations |
| GVF iterations = 0 |  |  |

Subsequently, the GVF iterations were increased such that the size of the external field becomes larger, such that it exerts a force onto the snake. A comparison was made between a snake whose and , and one whose and . What was observed is that alpha negatively affects the ability of the snake to conform to the image. This is because shrinks the snake, while the external force is pulling the snake outwards to conform to the shape.

|  |  |  |
| --- | --- | --- |
|  | Before | After 40 iterations |
| GVF Iterations = 3 |  |  |
| GVF Iterations = 0 |  |  |