Canny 알고리즘을 활용한 경계선 검출의 발전

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Progress of Edge Detection Using Mean Shift Algorithm

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요 약

영상에서 경계선의 추출의 저수준 영상 처리에서 매우 중요하다. 하지만 대다수의 경계선 추출 방법들은 노이즈들의 영역이 많기 때문에 효율적이지 못하고 영상이 서로 다르기 때문에 유연하지 못하다. 본 논문에서는 이러한 문제 해결을 위하여 우선 노이즈 감소 단계를 제시한다. 그리고 점진적인 변화 폭의 히스토그램과 내부 클래스 최소 변이상의 양쪽 임계값들을 자동으로 선택하도록 한다.

키워드

Edge Detection, Noise, Low Level Image Processing, Histogram

Ⅰ. Introduction

In a digital image, the boundary of objects usually contains much information; although just include some few quantities of pixels out of the whole image. Therefore edge detection is an important and challenged task in image processing, image analysis and computer vision field. Hitherto the Canny algorithm already become one of the most suitable and common used method among the others, so select Canny algorithm for edge detection is still main stream. However, there are two drawbacks plague it all the time, the first is it can't avoid the sensitive noise points effect, the second is it's parameters of both thresholds should be set artificially. Hypothetical situation, take the same image, stay in different circumstance, the both thresholds have to be set different from each other by person, let alone the different image. The result of being stubborn in the original Canny algorithm manifest the user have to set parameters every time. So that there are many masters research building thresholds automatically method thorough the world [1] ~ [3], and bring the alleged self adaptive methods who have also need to set the scale coefficient of threshold. That can't shrug off the human factor as well.

Ⅱ. Related Work

Till now, how to set the low and high thresholds has no solid criteria, so decide them depend on experience can't avoid from influent of individual. But the Otsu's method assumes that the image to be thresholded contains two classes of pixels, the foreground and background, then calculates the optimum threshold separating those tow classes so that their combined spread is minimal. This method inspire the masters explore its scale and for more than one threshold selection in many fields. According to Otsu's description, minimizing the intra class variance $\sigma_w^2(t) = w_1(t)\sigma_1^2(t) + w_2(t)\sigma_2^2(t)$, is the same as maximizing inter class variance $\sigma_b^2(t) = \sigma^2 - \sigma_w^2(t) = w_1(t)w_2(t)[\mu_1(t) - \mu_2(t)]^2$, so from both of these aspects can find out the propose thresholds, and this portion is the kernel in recently years research.

III. Self adaptive Canny Algorithm

The original Canny algorithm adopt the finite differential of adjacent area's first partial derivate to calculate the data matrix $I(x,y)$'s gradient amplitude and orientation. The partial derivate of x and y's 2 matrixes, which are $P_x[i,j]$ and $P_y[i,j]$:

$P_x[i,j] = (I[i,j+1] - I[i,j] + I[i+1,j+1] - I[i+1,j])/2$,

$P_y[i,j] = (I[i,j] - I[i+1,j] + I[i,j+1] - I[i+1,j+1])/2$.

Pixel's gradient amplitude and orientation use convert formula rectangular to polar to figure out: the gradient amplitude is $M[i,j] = \sqrt{(P_x[i,j])^2 + (P_y[i,j])^2}$, and the gradient orientation is $\theta[i,j] = \arctan(P_y[i,j]/P_x[i,j])$. Then in order to extract the single pixel thick edge, we have to make out thinned amplitude image. However, near the position of maxima $M[i,j]$ will appear ridge; maintaining the maxima regional change point of amplitude can determine the edge position accurately, and this procedure is the alleged non-maxima suppression. In this section, the Canny algorithm use the magnitude of 3×3, 8 directions adjacent area interpolate all pixels of amplitude matrix $M[i,j]$ along the gradient direction. On every point, compare the adjacent area center pixel $m[i,j]$ with the two interpolation result along the gradient direction. If adjacent area center point' amplitude $M[i,j]$ is not large than both interpolation results, assign the edge corresponding $m[i,j]$ to zero. This procedure details the ridge into one pixel magnitude, and maintains the gradient amplitude at the same time.

After the above steps, we have to determine the double thresholds and connect the edge. Undergone the non-maxima suppression and set both high threshold H_{T_H} and low threshold H_{T_L} for the sub-image $N[i,j]$ of gradient histogram, assign zero to the pixel whose gray vale is less than the threshold, then get two edge images $T_h[i,j]$ and $T_l[i,j]$. The $T_h[i,j]$ who through high threshold include very few fake edges, while $T_l[i,j]$ is opposition, consist of detail information but many more fake edges. Therefore combine both of them can get plausible edge [6].

According to these descriptions, the both thresholds determination can't refrain from the effect of personal factor, so need some method can absolutely exclude the personal factor and automatically determinate the thresholds hinge on different images. Inspirited by the Otsu's method [7], adopt the improved approach which based on gradient amplitude histogram and intra class variance to make out the both thresholds and then undertake non-maxima suppression to select the proper points, accomplish edge detection finally.

The gradient amplitude through non-maxima suppression is compose of L level, modulus maxima separate into three classes: C_0, C_1, C_2, C_0 class is the pixel that didn't belong to edge, C_2 class is the pixel belong to edge, C_1 class include the rest limbo pixels. Assume n_i is the amount of pixels whose modulus is i, P_i is the ratio of this kind of pixel to the whole pixels: $P_i = \frac{n_i}{N}, p_i \geq 0, \sum_{i=0}^{L-1} P_i = 1$, let C_0 include the pixels whose modulus is $[0,1,\cdots,k]$, C_1 include the pixels whose modulus is $[k+1,k+2,\cdots,m]$, C_2 include the pixels whose modulus is $[m+1,m+2,\cdots,l-1]$:

$$\mu_T = \mu(l-1) = \sum_{i=0}^{l-1} ip_i,$$

$$\begin{cases} \omega_0(k) = \sum_{i=0}^{k} P_i, \omega_1(k,m) = \sum_{k+1}^{m} p_i, \\ \omega_2(m) = \sum_{m-1}^{l-1} p_i, \mu_0(k) = \frac{\sum_{i=0}^{k} ip_i}{\omega_0}, \\ \mu_1(k,m) = \frac{\sum_{i=k+1}^{m} ip_i}{\omega_1}, \mu_2(m) = \frac{\sum_{i=m+1}^{l-1} ip_i}{\omega_2}, \end{cases}$$

$$\begin{cases} \sigma_0^2 = \frac{\sum_{i=0}^{k}(i-\mu_0)^2 p_i}{\omega_0}, \\ \sigma_1^2 = \frac{\sum_{i=k+1}^{m}(i-\mu_1)^2 p_i}{\omega_1}, \\ \sigma_2^2 = \frac{\sum_{i=m+1}^{l-1}(i-\mu_2)^2 p_i}{\omega_2} \end{cases}$$

Propose the evaluate function "based on gradient amplitude histogram and minimized intra class variance determine the two thresholds":

$J(k,u) = Arg\min(\sigma_w^2) = Arg\min(\omega_0\sigma_0^2 + \omega_1\sigma_1^2 + \omega_2\sigma_2^2)$.

Minimized intra class variance reflects the difference between the different classes should be minima. Through this procedure convert itself into first order statistical data, get the result has the advantages that easy to figure out and code out. There is the inference:

$$J(k,m)=\int_0^k (i-\mu_0(k))^2 p_i di+\int_{k+1}^m (i-\mu_1(k,m))^2 p_i di+\int_{m+1}^{l-1} (i-\mu_2(m))^2 p_i di,$$

$$\frac{\partial J(k,m)}{\partial k}=(k-\mu_0(k))^2 p_k-2\mu_0^{(1)}(k)\int_0^k (g-\mu_0(k))p_i di-(k-\mu_1(k,m))^2 p_k-$$

$$2\mu_1^{(1)}(k,m)\int_m^{k+1} (g-\mu_1(k,m))p_i di.$$

From mathematical statistics we know that: if $\int_0^k (g-\mu_0(k))p_i di=0$, than

$$\frac{\partial j(k,m)}{\partial k}=[k-\mu_0(k)]^2 p_k-[k-\mu_1(k,m)]^2 p_k.$$

Let $\frac{\partial J(k,m)}{\partial k}=0$, and simplify the equation than get $2k-\mu_0(k)-\mu_1(k,m)=0$. In a similar way: $2m-\mu_1(k,m)-\mu_2(m)=0$ [8].

From the above proof process, get the results that m,k are the most suitable extreme points for split. After that use fuzzy control method filter the pixel between the both thresholds.

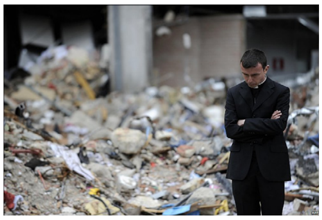
When adopting both thresholds to filter the maximum modulus undergone the non-maxima suppression, fade out the point whose modulus is less than the low threshold as the non boundary point, while maintain the point that is large than the high threshold as the boundary point. But the pixel between the both thresholds can't decide. Because there is one regional peak in any boundary and its vertical direction, hence decide whether the maximum modulus between both thresholds is the boundary or not. According to some point maximum modulus' direction, determine the direction of boundary, and select its line adjacent area at boundary vertical direction, there are two pixels on this point's every side. If its maximum modulus is the most among its adjacent area, it is boundary point, otherwise is not. Using fuzzy control algorithm extract the pixel between the thresholds, set up membership function depending on maximum modulus $Mf_{2^j}(x,y)$, and undertake edge extraction and connection:

$$\mu(Mf_{2^j}(x,y))=\begin{cases}1, Mf_{2^j}(x,y)\ge m,\\ 0, Mf_{2^j}(x,y)\le k,\\ \{1+[q_{\max}-Mf_{2^j}(x,y)]^2\}^{-1}, k<Mf_{2^j}(x,y)<m.\end{cases}$$

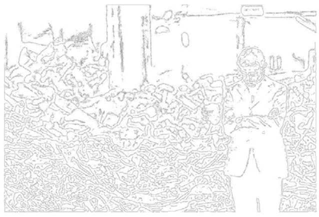
The $q_{\max}$ is the largest one among the 5 pixels which perpendicular to edge direction. And the membership show that, if the maximum modulus of decision point is not the largest among the adjacent area, this point must not belong to the edge; if it is, it belongs to the edge definitely [9].

Ⅳ. Experiment

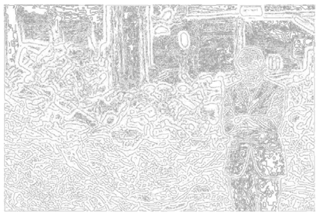
Take experiment to compare the original Canny method with the improved method combined Mean Shift smoothing and self adaptive thresholds selection, the result is obvious different:



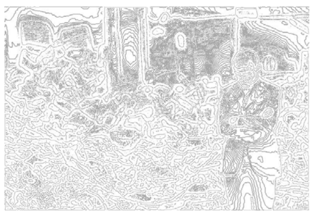
The original image



The original Canny algorithm, where σ =0.4, L_{ratio} =0.4, H_{ratio} =0.8;



The result of using self adaptive Canny algorithm



The result of Mean Shift smoothing plus self adaptive Canny algorithm, where h_s =32, h_r =16

Ⅴ. Conclusion

The Mean Shift eliminates the sensitive noise points at first, and then improves the original Canny algorithm by intra class variance minimum theory, select the both thresholds automatically, in the end can get better result than the original approach. However, both of the methods' natural drawbacks lower the efficiency each other, and how to set the necessary parameters of both seem as very important.

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