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A Study on Segmentation of Bite Mark Images Using Chan-Vese Method and Canny Algorithm

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Abstract: ***Now a days, Bite mark investigation plays a vital area in forensic image processing, and is treated as a common way of dental proof offered in assisting criminal cases. The bite marks of suspects are compared with victim using the required measurements. This paper presents an effective bite mark investigation using Chan-vese segmentation. The proposed model includes two processes, specifically enhancement and segmentation. At the earlier stage, Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied for image enhancement. Then, the processed image undergoes segmentation process by using Chan-vese method and Canny edge detection method. In this, Chan-vese method is more effective in detecting the edges of bite mark images whereas Canny algorithm is less effective in detecting the edges. Therefore Chan-vese method has an effective approach than Canny algorithm in detecting bite mark edges.***

Keywords: Chan-vese Segmentation, Canny Edge Detection, Bite mark, Median Filter

1. Introduction

Bite mark evidence is one way of identifying suspect in forensic studies. Furness defined that "A suspect might lie through his teeth though teeth themselves cannot lie" of recognition of fingerprints and DNA examination in forensic studies. Anything different from ordinariness has become a significant model while demanding to create an individuality of suspects [1]. Bite mark is "a mark made by teeth or in mixture of some mouth parts" [2], [3]. It is a kind of 'pattern injury', indicating that the pattern is produced by specific objects. In some cases, they are referred as 'tool marks. Bite marks could be present in the alive or dead person, whom might be a victim of the offense or the performer of the crime. It might occur at any objects in the crime scenario. Bite marks can be made at the time of physical attack, child abuse or adults linked to sex relevant crimes [4]. It can be occurred at any place of the body, and particular parts are linked to some kinds of offense. Some parts such as neck, breast and shoulder are frequently bitten in a sex based offense, whereas in child abuse scenarios, the commonly bitten areas are arm and buttocks. Youngster self-inflicted bites can be found on the medicinal view of the arms.

a) Categories

The bite marks can be classified into several types as explained below.

Tooth pressure mark: It occurs through the incisal edges of the frontal teeth. It is steady and results to low deformation.
Tongue pressure mark: Due to tongue pressure, impression of palatal surface of teeth, cingulum or palatal rugae might be created. It leads to distortion of the marks.

Tooth scrape mark: It is generated due to the irregularity present in the teeth because of fracture, restoration, and so on.

Complex mark: It indicates an integration of the above kinds of marks. The structure depends upon the quantity of tissue comes from the mouth [5].

b) Difficulties in bite mark examination

Some of the complexity present in the examination of bite marks are listed below.

Correctness of the bite imprint: The mark might not be precise because of the irregularities present in the affect's regions on the human skin and low quality of the substance and time period from bite mark and model generation.

Permanency: Dissimilar to fingerprints that are realistically stable over the time period in a person's life, the dentition has the capability of significant variations in configuration, with and without specialized involvement. A variety of restorative materials could alter the characteristics of the bitten areas or the real location of the person's teeth. Disease progression could also alter the marks.

Location: It has difficulty in finding anatomical location of bite marks [6].

Bite marks might be present on the victim body, chewing gum, pencil, or pens and furthermore occurred on musical instrument, cigarette, food material like cheese, fruits, vegetables, chocolates, etc. They are occurred particularly in scenarios like homicide, quarrel, kidnap, child abuse, and sexual attack and during sports events and occasionally deliberately inflicted to frame someone inaccurately [7].

When bite marks on the body are deliberately created, whereas marks occurred on food substances are generally unnoticeably left by the criminal at the offense scenario. Therefore, to identify the criminal, the dental molds of suspects are produced by the use of dental materials and matched. Bite marks when examined correctly could ensure the presence of a specific person in a scrupulous crime [8].

It is believed that bite marks could be experimentally produced to a stage which allows comparing bites caused in aggressive or critical scenarios and, extensive researches needs to make by the use of living persons for exploring various experimental cases [9]. A significant and tedious issue in the forensic dentistry is the recognition, recovery, and examination of bite marks with the supposed offenders. Different models of bite mark examination exist like impression creation from bitten materials using dental stone and hand tracing from dental study casting, photographic model, photocopy, and computer-aided overlay creation approach [10].

Earlier works recommended that computer based overlay has offered a precise and reproducible exemplars [11]. A main variable employed in the examination is inter−canine distance (ICD), as the impression of the frontal teeth is typically the obvious and probable to be quantifiable. [12] intended to examine and differentiate the gender discriminate of gender using an effective computer based model and clarify its application in forensic odontology. This paper concentrates on the utilization of image processing techniques such as preprocessing and segmentation of bite marks to identify the suspects by the use of bite marks left in crime scenario. A bite mark investigation by the use of Chan-vese segmentation is used here. The proposed Chan-vese segmentation then compared with Canny algorithm to detect bite mark edges effectively.

2. Proposed Method

This approach comprises a group of three processes, specifically pre-processing, segmentation and classification. At the beginning stage, Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied for image enhancement. Then, the preprocessed image undergoes segmentation process by the use of Chan-vese method and Canny edge detection method. Finally, the Chan-vese segmented images are compared with the images of canny edge detection algorithm.

a) Preprocessing

Basically, Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied for image enhancement.

The background contrast has improved after applying histogram equalization. So as to solve this problem, adaptive histogram equalization is used. Adaptive HE (AHE), which divides the images into regions and performs local HE.

AHE can over-amplify the contrast in near-constant regions of the image.

Contrast limited AHE limits the contrast amplification to reduce amplified noise. It does so by distributing that part of the histogram that exceeds the clip limit equally across all histograms.

Fig. 2 depicts sample input image and the Enhanced image by applying CLAHE technique. From Fig. 2a, the original input bite mark image is provided and the corresponding Enhanced image is illustrated in Fig. 2b.

(a) (b)

Figure 2: (a) Original Image (b) Enhanced Image

b) Chan-vese segmentation

We use this technique to detect region and boundaries and to isolate and extract individual components from the pre-processed images. This segmentation results more closer boundary to the actual region.

Chan vese method: Active contour model, or snakes, proposed by Kass et al., 1988. [13] has been proved to be an efficient framework for image segmentation. Since the active contour model was proposed, many methods have been proposed to improve it, in which level set method proposed by Osher and Sethian, 1988. [14] is the most important and successful one.

Region-based level set methods (Tsai et al., 2001, [15]; Gao and. Bui, 2005) [16] have been proposed and applied to image segmentation filed by incorporating region-based information into the energy functional. Unlike edge-based level set methods using image gradient, region-based methods usually utilize the global region information to stabilize their responses to local variations (such as weak boundaries and noise). Thus, they can obtain a better performance of segmentation than edge-based level set methods, especially for images with weak object boundaries and noise. Among the region-based methods, Chan-Vese model is one of the most popular.

Based on the Mumford and Shah (1989). [17] for segmentation, Chan and Vese, 2001. [18] proposed an easily handled model, or called Chan-Vese (CV) model, to detect objects whose boundaries are not necessarily detected by the gradient Mumford-Shah model was firstly proposed as a general image segmentation model by Mumford and Shah. Using this model, the image is decomposed into some regions. Inside each region, the original image is approximated by a smooth function. The optimal partition of the image can be found by minimizing the Mumford-Shah functional. Chan and Vese successfully solved the minimization problem by using level set functions, which utilized the global image statistics inside and outside the evolving curve rather than the gradients on the boundaries.

The Chan Vese (CV) model is an alternative solution to the Mumford-Shah problem which solves the minimization of Mumford-Shah energy functional by minimizing the following energy functional:

$$E_{CV}(c_1, c_2, C) = \mu.\text{Length}(C) + ?_1 . \int_{\text{inside}(C)} |\mu 0(x,y) - c_1|^2 \, dx\, dy + ?_2 . \int_{\text{outside}(C)} |\mu_0(x,y) - c_2|^2 \, dx\, dy$$

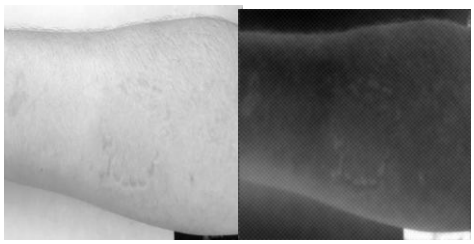
where p, A, and A, are positive constants, usually fixing Al A2 = 1. cl and c2 are the intensity averages of pp inside C and outside C, respectively. To solve this minimization problem, level set method is used which replaces the unknown curve C by the level set function 4) (x, y), considering that 4' (x, y)> 0 if the point (x, y) is inside C, (x, y) <0 if (x, y) is outside (x, y) and (x, y) = 0, if (x, y) is on C. Thus, the energy functional Ecv (cl, c2, C) can be reformulated in terms of the level set function 4) (x, y) as follow:

$$E_{CV}(c_1, c_2, f) = \mu . \int_{\Omega} d_e(f(x,y)) |\nabla f(x,y)| dx\, dy + ?_1 . \int_{\Omega} |\mu_0(x,y) - c_1|^2 H_e(f(x,y)) | dx\, dy + ?_2 . \int_{\Omega} |\mu_0(x,y) - c_2|^2 (1 - H_e(f(x,y))) | dx\, dy$$

where, g (z) and 8c are, the regularized approximation of Heaviside function H (z) and Dirac delta function 8 (z) as follows:

$$H(z) = \begin{cases} 1 & \text{if } z \geq 0, \\ 0 & \text{if } z < 0, \end{cases} \qquad d(z) = \frac{d}{dz} H(z)$$

This minimization problem is solved by taking the Euler-Lagrange equations and updating the level set function by the gradient method.



(a) (b)

Figure 3: (a) Enhanced Image (b) Chan-vese Segmented Image

Fig. 3 shows the sample preprocessed image and the segmented image using Chan-vese technique. From Fig. 3a, the preprocessed bite mark image is provided and the corresponding segmented image is illustrated in Fig. 3b. It can be observed that the bite mark can be clearly noticed in the segmented image.

c) Canny edge detection algorithm

In 1986, Canny edge detection operator was proposed on optimization algorithms for edge detection. Relatively simple algorithm to make the whole process effectively is executed and has been widely used but Canny operator has the defect that being vulnerable to various noise disturbances. Thus, there are certain limitations of its concrete application (Wang and Fan, 2009) [19].

The detecting process of the Canny algorithm consists of the following steps (Pan and Wang, 2008) [20]:

Step 1: Use the Gaussian filter smoothing image to restrain noise

Step 2: Calculating the gradient magnitude M (x, y) and the gradient direction H (x, y) of the image M (x, y)is defined as follows:

$$M(x.\ y) = \sqrt{E_x(x,y)^2 + E_y(x,y)^2} \qquad (1)$$

The H(x.y) is defined as follows:

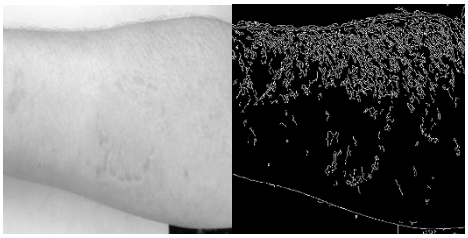
$$H(x\ y) = \arctan [E_x(x,y) / E_y(x,y)] \qquad (2)$$

E_x and E_y are the result what the image being affected by the filter along the row-column direction:

Step 3: Do non-maximum suppression for the gradient magnitude

Step 4: Dual-Threshold algorithm is adopted to detect and connect edges

The canny algorithm uses Gaussian filter that smoothen the edges more leads to some isolated and false edges.



(a) (b)

Figure 4: (a) Enhanced Image (b) Canny Segmented Image

Fig. 4 shows the sample preprocessed image and the segmented image using Canny algorithm. From Fig. 4a, the preprocessed bite mark image is provided and the corresponding Canny segmented image is illustrated in Fig. 4b. It can be observed that the bite mark can be noticed in the Canny segmented image.

3. Methods of Comparison

In Fig. 2a, it is the original input bite mark image. The result in Fig. 4b, using Canny algorithm can produce more noise and more false edges. Canny edge detector can extract boundaries but due to abrupt change in brightness levels of image, correct and smooth edges are not obtained. More accurate one would be obtained if morphological operator is applied to remove small voids and short lines. Hence it is less suitable for use in the bite mark image. The result of Chan-vese method is shown in Fig. 3b. It is achieved effectively by selecting the best edge information required.

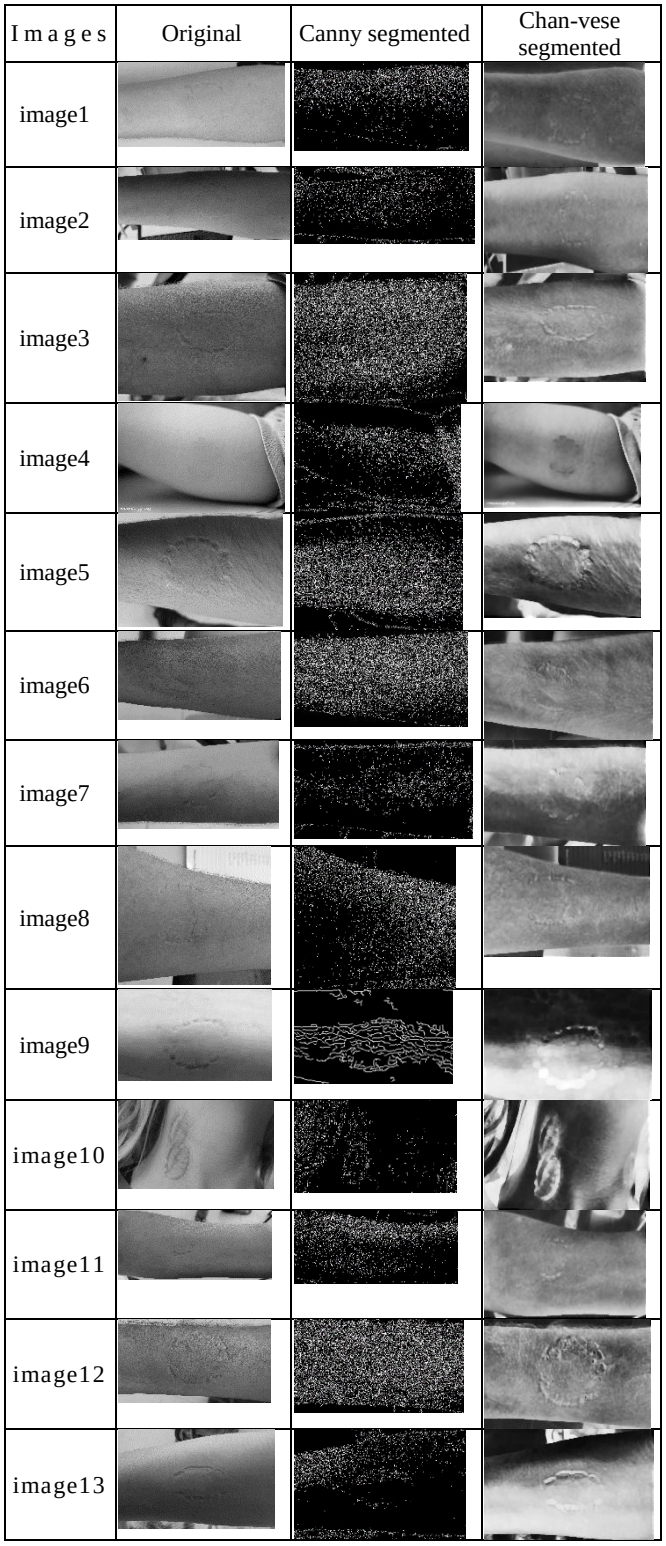


Figure 5: Experiment results of the bitemark images comparison using Canny algorithm and Chan-vese method

It is the ratio between maximum power of the signal and the power of corrupting noise. The more the value of PSNR the better is image reconstruction ability. PSNR comparison values between canny edge detector algorithm and chan-vese method of a set of 13 images are shown in Table 1:

Table 1: Comparison of MSE, PSNR values of bitemark images using canny algorithm and chan-vese method

Image	Canny algorithm		Chan-vese method	
	MSE	PSNR/dB	MSE	PSNR/dB
image1	0.00001	29.439	0.00001	48.451
image2	0.00001	29.820	0.00002	46.846
image3	0.00003	24.898	0.00002	46.372
image4	0.00002	27.145	0.00002	46.350
image5	0.00002	27.119	0.00003	45.505
image6	0.00002	26.969	0.00003	45.931
image7	0.00001	29.327	0.00001	48.798
image8	0.00002	27.358	0.00002	47.290
image9	0.00003	25.882	0.00000	54.917
image10	0.00001	30.445	0.00004	44.300
image11	0.00003	27.683	0.00007	41.585
image12	0.00002	22.395	0.00004	44.524
image13	0.00002	29.379	0.00008	41.021
Average	**0.00002**	**27.52762**	**0.00003**	**46.29923**

From the comparison of above two edge detection techniques chan-vese is best and produce better output in terms of PSNR, MSE than canny edge detection algorithm. The chan-vese method also gives the more quality image in terms of PSNR, MSE compared to canny edge detection algorithm.

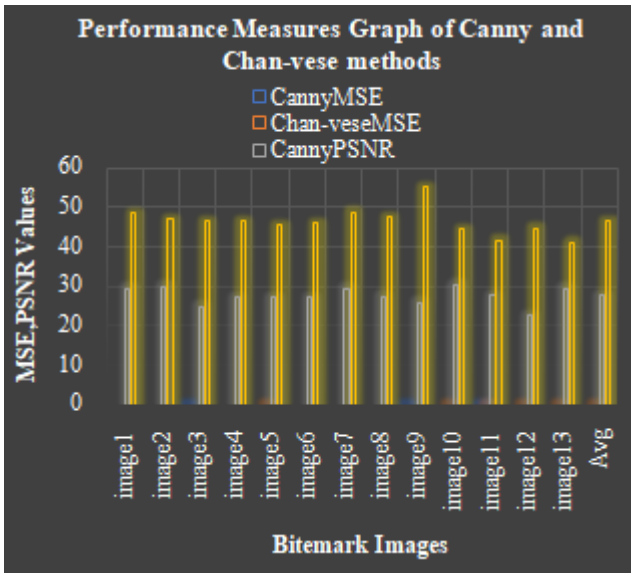


Figure 6: MSE, PSNR Graph of Bitemark Images Comparison using canny algorithm and chan-vese method

In Fig.6, the performance graph of Mean Square Error and Peak Signal Noise Ratio of bitemark images are measured. MSE represents the cumulative squared error between the bitemark images using canny algorithm and chan-vese method, whereas the PSNR represents a measure of peak error between the bitemark images using canny algorithm and chan-vese method. The PSNR usually represents in terms of the decibel (dB) scale.

In summary, it is noticed that the Chan-vese segmentation method is more effective than Canny edge detector algorithm. Therefore, the presented Chan-vese segmentation can be effectively utilized to detect the bite marks found on the skin.

4. Conclusion

This paper has focused on the usage of image processing

techniques such as preprocessing and segmentation of bite marks to identify the criminal suspects by the use of bite marks left in crime scenarios.

In this study, Canny algorithm and Chan-vese method for bite mark edge detection approach have been successfully applied and the image quality metrics performance based on the two metrics, Mean Square Error and Peak Signal to Noise Ratio. The higher in PSNR values indicates the higher in quality. By Canny algorithm, some false edges occur. While using Chan-vese approach for bite mark edge detection, we can effectively segment the image without affecting the integrity of the further processing.

Therefore, the presented Chan-vese method can be utilized effectively to examine the bite marks found on the skin. In future, the performance of the proposed model can be further improved by the use of newly developed techniques.

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