IEEE NNC Summer Research Project Report 2000

The nth -term Generalized Fuzzy Tree Algorithm applied in Edge Detection

Mr. Chung-Chu Leung, PhD candidate

Biomedical Engineering Center

Department of Electrical & Electronic Engineering

The University of Hong Kong

Hong Kong, China

1. *Research Proposal*

1.1 INTRODUCTION

Digital subtraction radiography has been shown to improve the detection of minute bone changes in patients having dental implants or periodontal diseases [1-3]. However, intra-oral radiographs may be bent by the musculature of the oral cavity during the image capturing process. These distortions cause problems in the perfect alignment of the pair of radiographs for comparison, and can jeopardize the subtraction results. Some methods [4-6] proposed to minimize the bending error using image processing technique, but no single method solves the problem satisfactory. We have developed and propose a tooth model to make the best alignment in the bend intra-oral radiographs. First, a surface tooth model "A" in the no bend image will be created as the reference. Second, another surface tooth model "B" is then set up in the bend image. Model B can be contracted and expanded to fit the shape based on surface fitting algorithm to the reference Model A. However, one main problem of this idea is arisen in the detection of the tooth edge. No good methods can detect a fine edge in the base of the tooth in intra-oral radiographs. It is because the soft-tissue covers the base so that the clear edge of the tooth will not be found easily by conventional edge detection methods. Consequently, the best reference tooth model and the bend tooth model cannot be created accurately.

A Generalized Fuzzy Edge Detection Method has been developed based on the improved Generalized Fuzzy Operator (GFO)[7-8]. It was satisfactory when used to detect the boundary of the tumor cells in the Morphometric assessment. The characteristics of the improved GFO is a V-shaped curve located in [-1 1] of *S*. *S* when mapped to the new fuzzy set *T*. A newer image can be obtained based on the new fuzzy set *T*. This function resembles a band-pass function in which the edge pixels are mapped to a range of values distinct from each other. However, the simple V-shape curve was not satisfactory in the subtraction radiograph of our project.

1.2 GENERALIZED FUZZY EDGE DETECTION METHOD

Definition 1. Denote the Generalized Fuzzy Set (GFS) *S* in the region *R* as

$$S = \int \frac{\mu_S(x)}{x}, x \in R \qquad (1)$$

Where $\mu_S(x) \in [-1,1]$ is called the Generalized Membership Function (GMF) of *S* on *R*. Since $\mu_S(x) \in [-1,0)$. The GMF of *x* in *S* is not a subordinate on R, for $\mu_S(x) \in [0,1]$. The GFM of *x* in *S* is subordinate on *R*; and $\mu_S(x) = 0$. The fuzzy bound point function (FBF) in *S* is on *R*.

According to the definition by Chen et al, we can write,

$\mu_T(x)$ = GFO[$\bullet_s(x)$] =

$$\begin{cases} \sqrt[\beta]{1-[1+\mu_s(x)]^\beta}, & -1 \le \mu_s < 0 \\ [\mu_s(x)]^\beta, & 0 \le \mu_s < r \\ \sqrt[\beta]{1-\alpha[1-\mu_s(x)]^\beta}, & r \le \mu_s(x) \le 1 \end{cases} \qquad (2)$$

From (2), we can deduce the following properties:

Property 1. When $\beta \to \infty$,

$$\mu_T(x) = \begin{cases} 1, & -1 \le \mu_s(x) < 0 \\ 0, & 0 \le \mu_s(x) < r \\ 1, & r \le \mu_s(x) \le 1 \end{cases} \quad (3)$$

Property 2. When $\beta > 1$,

$$\begin{cases} \mu_T(x) > \mu_S(x), if \ -1 \le \mu_S(x) < 0, \\ \qquad\qquad\qquad r < \mu_S(x) \le 1 \\ \mu_T(x) < \mu_S(x), \ \ if\, 0 < \mu_S(x) \le r \end{cases} \quad (4)$$

Then the generalized fuzzy set *S* becomes a normal fuzzy set *T*, such that

$$T = \mathrm{GFO}[S] \quad (5)$$

1.3 THE MODIFIED GENERALIZED FUZZY EDGE DETECTION METHOD

Although the properties of the Generalized Fuzzy Edge Detection Method include a shape V-shaped type bandpass and an enhancement function in the feature of the image as well, these functions are ineffective in case of searching the boundary of the tooth.

A modified Generalized Fuzzy Edge algorithm is developed and it can solve the above problem.

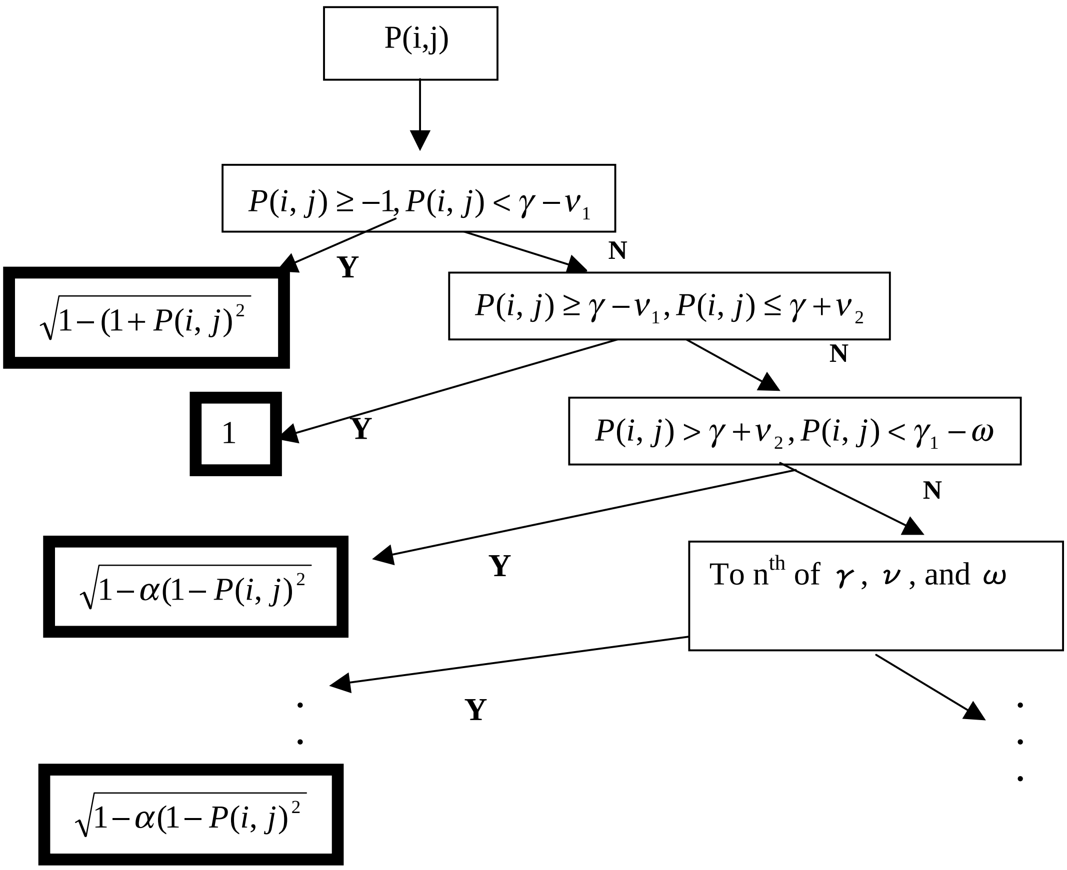
A) Definition of the n^{th} -term Generalized Fuzzy Tree Algorithm

The improved generalized Fuzzy Edge Detection algorithm is developed and shown in the following equations. According to equation (5), a new property set P' is developed and shown in equation (8), we set n = 3.

$$P'(i,j) = \begin{cases} \sqrt{1-(1+P(i,j)^2}, & -1 \le P(i,j) \cup (\gamma - v_1) > P(i,j) \\ \sqrt{1-a(1-P(i,j)^2}, & (\gamma + v_2) < P(i,j) \cup (\gamma_1 - \omega) > P(i,j) \\ \sqrt{1-a(1-P(i,j)^2}, & (\gamma_1 + \omega) < P(i,j) \cup (\gamma_2 - \varsigma) > P(i,j) \\ \sqrt{1-a(1-P(i,j)^2}, & (\gamma_2 + \varsigma) < P(i,j) \cup 1 > P(i,j) \\ 1 & \Re \end{cases} \quad (6)$$

$$
\text{Where } \Re = \begin{array}{l} [(\gamma - v_1) \le P(i,j) \cup (\gamma + v_2) \ge P(i,j)] \cap \ldots \\ [(\gamma_1 - \omega_1) \le P(i,j) \cup (\gamma_1 + \omega_2) \ge P(i,j)] \cap \ldots \\ [(\gamma_2 - \varsigma_1) \le P(i,j) \cup (\gamma_2 + \varsigma_2) \ge P(i,j)] \end{array}
$$

The equation of the newer image $X'(i,j)$ remapped by equation (6) is the same as the equation (5). In this new fuzzy set, $P'(i,j)$ satisfying the properties shown in equation (6) is extended to the nth term by the following tree (**Y** means YES; and **N** means NO):



B) The properties of the n^{th} -term Generalized Fuzzy Tree Algorithm

From equation 6, there are more than nine parameters included in the generalized fuzzy set. For our new GFS design, there are only three sets of parameters to be adjusted for different images. Parameters α, n, and D can be fixed by the parameter analysis. α is a parameter which is used to control the contrast of the resultant image. The number of term n is the number of pixel band that is resolved by the user according to the region of image being selected. *D* is the main parameter in this algorithm. It affects the shape of Sinc function denoted in equation 5. In our experience, *D* is normally selected between 95 to 105. For our application, “100” is the standard choice. For the other sets of parameters, γ, ν, *and* ω are used to adjust the width of each specific zero region. If the width of the region is smaller, the value of ν, *and* ω should be in a higher level. Normally, γ is the main factor to locate edges. This n^{th} term Generalized Fuzzy tree algorithm is based on the Generalized Fuzzy Edge Detection Method so that the advantage in enhancement of the image is also preserved.

2. ***Results***

Figure 1(b) is the result of the simulation image of Figure 1(a). The Chinese characters and the Arabic numeral “9”are located in different gray level scales. Normally, the common edge detection methods cannot be detected its edge directly. However, the result of the new algorithm is quite good as shown in the Figure 1(b).

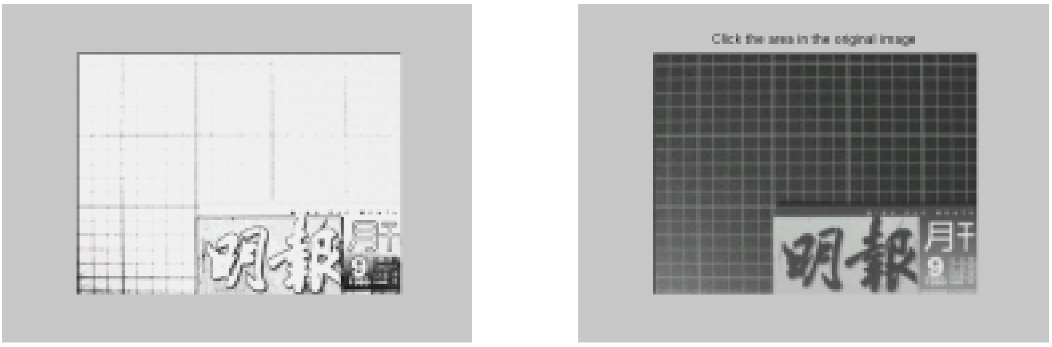
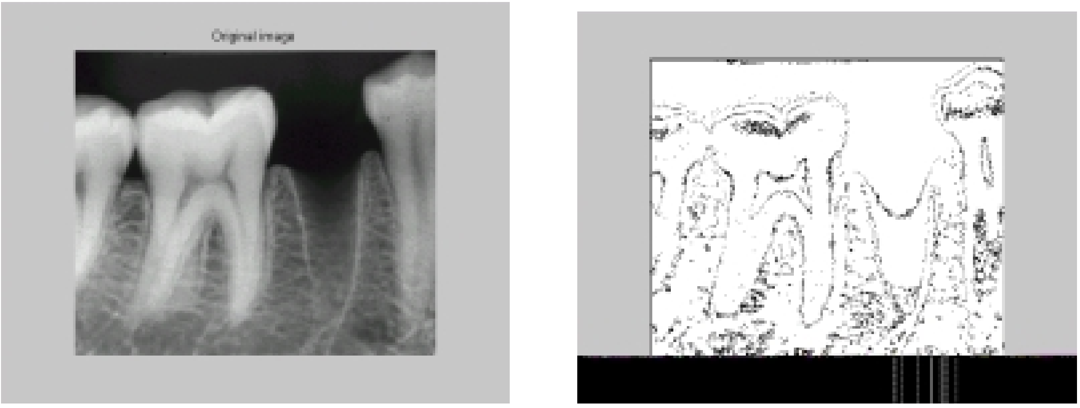


Figure 1. (a) shows the original image which includes Chinese characters and an Arabic numeral, and the result of using the modified generalized fuzzy edge algorithm is shown in (b).

The other example is the radiograph of a tooth. Figure 2(a) shows the Molar tooth with soft tissue in the base of the tooth. Figure 2(b) shows the result of the image using our algorithm.



Figuer2. (a) is the original intra-oral radiograph showing one molar tooth, whose base is covered by the soft-tissue. (b) shows a quite significant distinction between the edge of the molar tooth and the tissue.

3. Future work

Edge detection of the teeth is the basic procedure in pairs of radiograph alignment. Fundamentally, an inaccurate image alignment is resulted in the application of conventional image alignment techniques especially on the bend images. Now, as the edge found in the radiograph, a tooth model can be created. A new motion estimation algorithm may be developed to make the image alignment with high accuracy. It is the future work which I will do.

REFERENCE

[1] I. Fourmousis, U. Burgin, M. Tonetti, and N.P. Lang, "Digital image processing I Evaluation of gray level correction methods in vitro", *Clin. Oral Impl. Res.*, pp.1-11, Sept. 1993.

[2] H.G. Grondahl, K. Grondahl, and R.L. Webber, "A digital subtraction technique for dental radiography", *Oral Surg.*, vol.55, number 1, pp.96-102, Jan. 1983.

[3] P.F. van der Stelt, W.J. van der Linden, W.G.M. Geraets, C.L. Alons, "Digitized pattern recognition in the diagnosis of periodontal bone defects", *Journal of Clinical Periodontology*, vol. 12, p.822-827, 1985.

[4] R.L. Webber, U.E. Ruttimann, and R.A.J. Groenhuis, "Computer correction of projective distortions in Dental Radiographs", *J. Den. Res.*, vol. 63, No. 8, pp.1032-1036, August 1984.

[5] C.C. Leung, F.H.Y. Chan, K.Y. Zee, P.C.K. Kwok, "Compensation of bending errors

in Intra-oral Radiographs using Block-by-Block Image Scaling", *IEEE Trans. on Biomedical Engineering.* (In manuscript).

[6] C.C. Leung, P.C.K. Kwok, K.Y. Zee, F.H.Y. Chan, and S.T.F. Lo, "Minimizing the bending error in Intra-oral Radiographs using Point-by-Point Interpolation with image scaling", Proceedings of the EMBEC'99, Part II, pp.1050-1051, Nov. 1999. Vienna.

[7] W.F. Chen, X.Q. Lu, J.J. Chen, and G.X. Wu, "A new algorithm of edge detection for color image: Generalized fuzzy operator", Science in China (Series A), Vol.38, No.3, pp.468-473, 1998.

[8] C.C. Leung, F.H.Y. Chan, W.F. Chen, P.C.K. Kwok and K.Y. Lam, "Thyroid Cancer Cells Boundary Location by a Fuzzy Edge Detection Method" ICPR'2000, Sept. 2000.

Supervisors : Prof. F.H.Y. Chan and Prof. W.F. Chen