Trial for Improvement of Visibility of Tumor by Three Digital Imaging Processing

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Abstract

To observe the internal of organ clearly, CT/PET and MRI are recently being used. But in order to save demerit toward the high cost and non-real time observation by these machines, diagnostic ultrasound system is remarked. But there are several problems around visibility through ultrasound. Artifact problem are followed by reflection/refraction at the organ borders, lack of directivity of shooting, or reinforcement of wave. In addition, vagueness and darkness are inferior to those for CT/PET or MRI.

In order to improve the image resolution along which wave is reflected on tumors by ultrasonic diagnostic equipment, the proposed functions are newly added. First one is duplicated function of two dimensional linear mapping, the second is Differential filter, and the last one is Median filter.

Keywords: Medical Imaging; ultrasound

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doi:10.1016/j.phpro.2010.01.051
1. Background

Ultrasound has no risk for being bombed compared with X-ray, and ultrasonography has lower cost and there is no special facility for installing the said machine. And it can detect polyp, tumor, calculus, or by almost real-time processing [1].

And organs which can be diagnosed is liver, gall, pancreas, kidney, bladder, appendix, womb, ovary, prostate, breast, carotid artery, thyroid, parotid, heart, and etc [2].

There are various characteristic for tumor in the aspect of shape, brightness, boundary with the other organs, in correspondence with whether it is benign or malignant.

In case of benign parotid tumor called warthin tumor shape of its tumor is settled at the parotid side and the boundary with the other organ is visibly remarkable [3] and the internal low echo area can be observed toward reinforcement at the backward area of its tumor [4].

And various shaped adenoma which is malignant by the 50% probability has settled shape inside parotid. Securing of visibility is very important for discovery of tumor for the judgment whether its tumor is benign or malignant, and classification of the severity from T1 to T4 of illness [5].

2. Basic Strategy

The first approach is multi-dimension scan. For original brightness scan, only forward prediction was used when deciding what the predicted value at the said location is. So for X-axis setting up prediction coefficient is done so as to make prediction error as small as possible [6] and in the latter part predicted value passes quantizer and then the image is coded repeatedly. But in the proposed way, four way scan is used with the meaning of both X-axis and Y-axis with backward and forward trace like Fig.1.

We assume hat(^) mark means the said pixels predicted value at the said position.

Then when we scan direction of W,
\[ B_{33}^W = a_{30}B_{30} + a_{31}B_{31} + \ldots + a_{32}B_{32}. \]

When we scan direction of S,
\[ B_{33}^S = a_{63}B_{63} + a_{53}B_{53} + \ldots + a_{43}B_{43}. \]

When we scan direction of E,
\[ B_{33}^E = a_{36}B_{36} + a_{35}B_{35} + \ldots + a_{34}B_{34}. \]
And when we scan direction of N, 
\[ B_{33,N} = a_{03}B_{03} + a_{13}B_{13} + \ldots + a_{23}B_{23} \]

And so as a result the last prediction value 
\[ \hat{B}_{x,y} \]

can be calculated as 
\[ (\hat{B}_{33,W} + \hat{B}_{33,S} + \hat{B}_{33,E} + \hat{B}_{33,N})/4 \]

so as to make prediction error smaller.

For the second function, the differential filter realizing high frequency pass is used inside the upper Figure so as that the said brightness \( B_{ij} \) is transformed as \( (ai,j-ai-1,j)+(ai-1,j-ai,j) \).

And for the third one, Median Filter is used so as that dimensional product of pixel along X-axis and pixel along Y-axis inside \( N1 \times N2 \) are lined up in the descending order and then make its center value as the value at each pixel which appears a part of output image in order not only to remove the high frequency area but also to store the brightness signal [7].

3. Detail of Proposed Ways

We thought upper three different concepts in order to make the image by ultrasound more clear.

3.1. Linear Prediction

When extracting the organ itself, based on difference between the density of organ and its statistical character, accurate suppress of noise can be studied defining feature parameters brought up from the predicting filter’s coefficients and prediction error on many dimensional self regression model.

Concretely to say, assumed that image location regulated as two dimensional random signal including the organ internal image is defined \( Au(x,y) \), Self Correlation Function at that location as 
\[ Au(t_x,t_y) = Au(0,0)\exp(-t_x^2 + t_y^2) \] by using negative exponential function.

Usually here the value of the brightness of each pixel can be estimated from that of surrounding pixel as redundant element.

So estimated value the brightness \( fs \) of the pixel \( s \) can be regulated as 
\[ a_nf_n + a_nf_0 + a_rc \] (It is assumed that each pixel is lined up as \( A, B, C, \ldots \) sequentially backward or forward of \( s \), and \( ax \) is correlation function)

In order to remove the redundancy which we cannot guess from the brightness of the surrounding pixels, linear prediction coding is used via communication path. Es means \( B_{x,y} \) - as a prediction error. Fig.2 shows algorithm of this prediction. To send only prediction error \( es \) without sending real value \( B_{x,y} \) from sender leads saving the bit numbers for quantization and at last reduce prediction error at decoding.

![Fig.2 Principles Coding side (A) and decoding side (B) for brightness.](image-url)
In this Algorithm we not only one way algorithm but also multi(4) way’s algorithm for improvement shown in Fig.3

\[ \hat{s}_i = aA + aB + aC + aA' + aB' + aC' \]

(aA,aB,aC,aA’,aB’,aC’:
Linear Prediction Coefficients, setup so as that prediction error is minimized)

Fig.3 Improvement of Linear Prediction.

3.2. Differential Filter

Fig.4 is algorithm of Differential Filter. This is executed utilizing the symptom by which characteristic of brightness around the organ boundary is little by little changed.

As for brightness Once we differentiate it in the 2 dimension area, a boundary between different materials will make one amplitude peak at its location as gradient, besides if we do it twice, two peaks of mountains will be made at + and – area of differentiated value as Laplacian. By subtracting Laplacian from the original brightness function, we can get the edging conspicuous function because the gap near its boundary will be bigger like Fig.4.

Fig.4 Improvement using Differential Filter.
3.3. Median Filter

When observing organ, sparse fine circular spots by difference between refraction ratio of each organ can be often detected, because group intervention of dispersed light are generated on various phase by reflection on live organ’s fragment which are enough smaller compared with the wavelength of ultrasound called Speckle [8]. We can see it like aggregate of random small glittering spots on B mode shown in Fig.5.

![Fig.5 Actual Speckles around Vocal tract.](image)

In order to remove such impulsive confusing noise of Speckle, Median Filter was used shown in Fig.6. In case of this Median Filter we take Median value as the center values whose surrounding 8 number have.

![Fig.6 Improvement Trial using Median Filter.](image)
4. Experiment

4.1. Test Procedure Filter

We experimented visibility toward subjective impression toward 3 subjects on below condition.

- Image File taking
  Jpeg taken from Ultrasound

- Ultrasound system itself
  UF5500 by Fukuda Elec.

- Organ
  Assumed by Phantom with circles/holes/ projections on oblique/horizontal/vertical way

- Formula for RGB to Dimness
  DCT/IDCT
  
  \[
  Y(\text{Brightness}) = 0.29900 \times R + 0.58700 \times G + 0.11400 \times B \\
  Cb(\text{Hue-1}) = -0.16874 \times R - 0.33126 \times G + 0.50000 \times B + 0x80 \\
  Cr(\text{Hue-2}) = 0.50000 \times R - 0.41869 \times G + 0.08131 \times B + 0x80
  \]

4.2. Result

We checked 3 persons × 100 data’s average MOS as impression of visibility. Table.1 is its result.

Process for removing artifact as median filter has been executed. Toward sequential additional functions, multi-way’s linear mapping and differential filter, only 2 dimensional linear mapping process was already done commonly at first. Table.1 shows average recognition ration toward vision by addition in order on the condition that 100 different images with holes/projections whose height (1 ~ 3mm) and diameter (1 ~ 5mm) are both various, are mocked as tumors of cancer, and are located at random inside phantom sunk in physiological salt solution.

Table 1. Gross Result

![Table 1](image)

Improving sequence was differed, 5.7% merit was got when median filter is setup prior to the multi-way’s linear mapping and differential filter than when it is done backward. So it is favorable for vision that Median filter, 2
dimensional Linear Mapping using four ways, and then differential filter are sequentially used after original processing one way 2 dimensional Linear maps.

5. Conclusion

By using Median filter, 2 dimensional Linear Mapping using four ways, and then differential filter sequentially the subjective visibility merit by 15.3% was gotten from 71.7% to 87.0%.

In order to remove redundancy for calculation of the optimized prediction error, initial one way mapping process should be omitted actually, making much of sequence of way 2 in Table.1.

But even if we try such, visibility is not reached to that for MRI or CT/PET as strict fact. In order to get more merit for visibility. Additional methodology for diagnostic ultrasound system should be thought from range resolution and azimuth resolution also by hardware approach.

5.1 Further Software Trial

By using Median Filter, function improvement by which we proceed such boundary edge highlighting process as differential filter or four ways linear mapping to parallel has some loss.

In order to avoid such a redundancy, the direction adoptive filter shown in Fig.7 can be also assessed instead of raw Median Filter unlike the prediction filter using neural network [9].

Significant method by which we decide what the center value is will be done so as that the change from the initial center value is as small as possible, besides removing impulsive noise.

Saving complicated image in correspondence with the focal points and merging them with visibility optimization is also a key of progress of visibility. Basic performance of ultrasound system is evaluated from azimuth resolution, range resolution, and transmission power in the aspect of hardware shown in Fig.8. From the point of view of azimuth/range resolution it is favorable that the higher frequency radiation is selected.

But transmission power of ultrasound must be optimized to secure visibility avoiding attenuation and too many layer vision. So result wavelength of ultrasound must be prudently chosen from view.
Basic Function which we can consider of visibility improvement from hardware side including the focal point variableness by change of propagation delay’s ratio between the side robe and main robe as parallel work of software approach shown in Fig.9.

We will keep on trying to secure better visibility with good balance for both of more clear edge detection and noise removing which protect misleading.

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