

On Capability of High Frequency Ultrasound Images for Quantitative Assessment of Collagen: Phantom and Vivo Tissue Case Studies

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Abstract

Collagen content and its configuration are considered to be among important criteria of healing in tissues. Therefore, developing a method to estimate these factors can benefit physicians in terms of valuable information. In this paper, we examine variation of collagens in tissue mimicking phantoms as well as in vivo tissue taking advantage of applying image processing techniques on ultrasound images of samples. In phantoms, as the base tissue we have used agar-water matrix material and graphite to simulate collagen, respectively. We also have used different concentrations of graphite to simulate different contents of collagen according to attenuation coefficient of ultrasound waves in soft tissue and its correlation with weight ratio of graphite. Experimental and simulation results show that increase in concentration of graphite in phantoms results in higher energy and more contrast level in B-Mode images ($r = 0.99$, $p < 0.001$ and $r = 0.96$, $p = 0.01$, respectively). In order to validate the results, the same algorithm has been applied on images of fauna's samples. The images have been acquired during the healing process of pressure wounds in the tissue. Validity of reported results in fauna's samples has been verified through histological studies. In general, results in this paper show the capability of ultrasound image processing in quantitative assessment of collagen.

Keywords: Numerical analysis, High frequency ultrasound images, Histology images, Tissue mimicking phantom, Collagen.

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¹ Collagen

² Attenuation coefficient

³ Backscattering coefficient

⁴ Acoustic property

⁵ Co-occurrence matrix

⁶ Echo

⁷ Tissue-mimicking-phantom

⁸ Agar

⁹ Agarose

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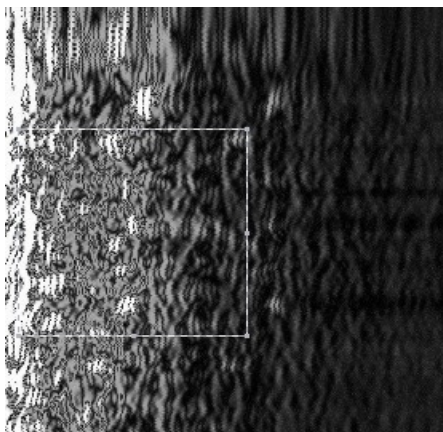
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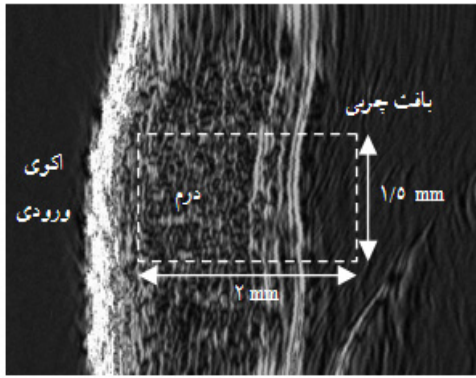
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RMS

$$= \sqrt{\frac{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (I(i,j))^2}{M \times N}}$$

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(i,j)

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¹² Van Gieson
¹⁶ Horizontal

¹³ Acoustic impedance
¹⁷ Diagonal

¹⁴ Contrast
¹⁸ Vertical

¹⁵ Root Mean Square
¹⁹ Antidiagonal

φ d . (° °)

:[] P(i,j)

$$0^\circ : P(I(m,n) = I_1, I(m \pm d, n) = I_2) = \frac{(I_1 \ I_2) \quad d}{\quad} \quad ()$$

B-Mode

$$^\circ : P(I(m,n) = I_1, I(m \pm d, n \mp d) = I_2)$$

$$^\circ : P(I(m,n) = I_1, I(m, n \mp d) = I_2)$$

$$^\circ : P(I(m,n) = I_1, I(m \pm d, n \pm d) = I_2)$$

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 (i,j)

$N_g \times N_g$

N_g

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$$\sum_{n=0}^{N_g-1} n^2 \left\{ \sum_{i=0, |i-j|=n}^{N_g-1} \sum_{j=0}^{N_g-1} P(i,j) \right\} = \quad ()$$

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$$LRE = \frac{\sum_{i=1}^{N_g} \sum_{j=1}^{N_r} (Q_{RL}(i,j) j^2)}{\sum_{i=1}^{N_g} \sum_{j=1}^{N_r} Q_{RL}(i,j)} \quad ()$$

$\sum_i \sum_j P(i,j)$

n

n

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LRE

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²⁰ Region Of Interest

²¹ Long run emphasis

$$[] = \frac{[]}{[]} \quad ()$$

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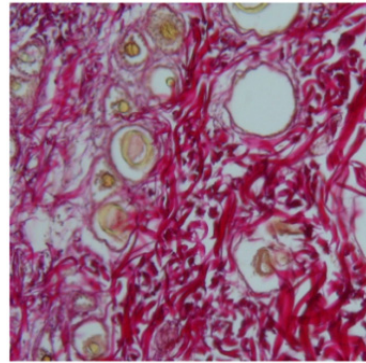
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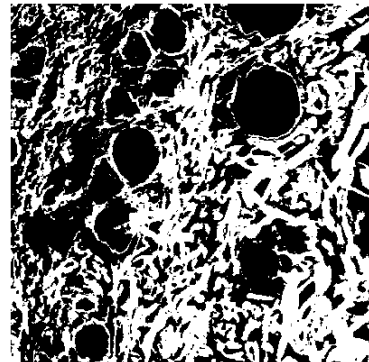
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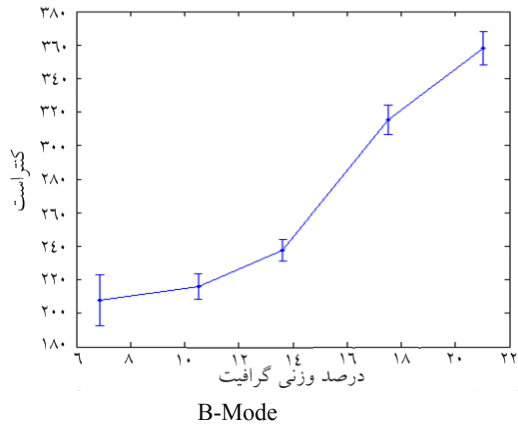


²² Red-Green-Blue
²⁶ Binary

²³ Hue-Saturation-Value

²⁴ Hue

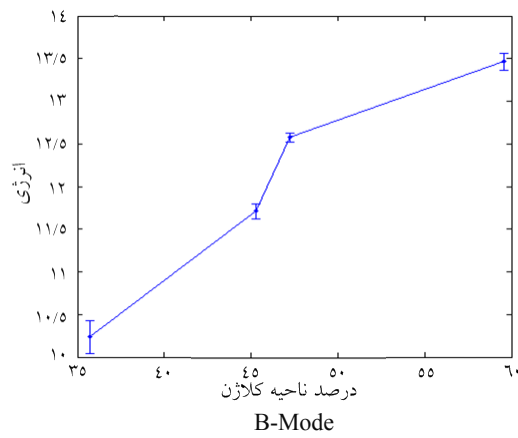
²⁵ Saturation



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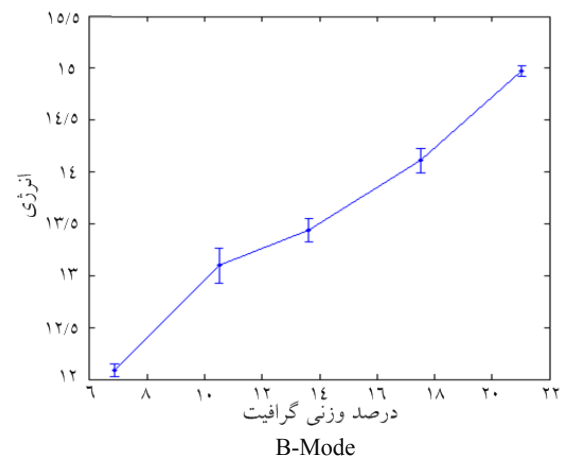
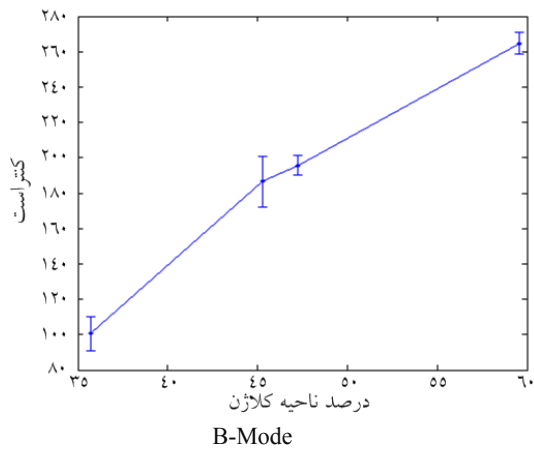
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ROI

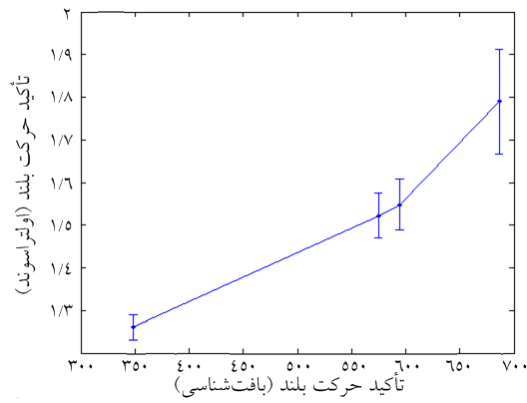
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