

OVARIAN ULTRASOUND IMAGE ENHANCEMENT BY PSEUDOCOLOURING

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Abstract

Image processing may be employed on ovarian ultrasound images to assist doctors in diagnostic analysis. The gray levels of ovarian images are usually concentrated at the zero end of the spectrum, making the image too low in contrast and too dark for the naked eye. This paper examines the effectiveness in displaying gray level ultrasound images as colour images and proposes a pseudocolouring approach for enhancing features in ultrasound ovarian image, which allows easy discrimination of texture information. A combination of the pseudocolouring method with other image enhancement manipulations such as contrast stretching and seed based region growing was also investigated. The combination of the pseudocolouring approaches with the other image enhancement techniques can dramatically increase the information in ovarian ultrasound.

Keyword:

Ultrasound, medical imaging, image enhancement, pseudocolouring

1. Introduction

Ultrasound is non-invasive and does not interfere with physiological functions. Repeat examinations are thus possible and the use of ultrasound enables observation of structures in the female pelvis. Acoustic speckle is a major source of ultrasound image texture information. But speckle also hurts contrast resolution and makes it difficult to see organ structures and subtle differences in tissue contrast [1]. The gray levels of ovarian ultrasound images are usually concentrated at the zero end of the spectrum, making the image too low in contrast and too dark for the naked eye. Image processing

is used to help doctors or sonographers to better diagnose these ultrasound images.

Colour images are widely been used in many applications but in medical imaging, gray-level images are still popular. The human eye is more sensitive to colour changes in images rather than intensity changes [2,3,4]. In certain applications, gray level images have colour that appear in the actual scene. Therefore, matching and transferring can be done to obtain colour images [5].

Currently, there are pseudocolouring methods that can be effectively increased by coding complex information in colours. This method is applied to gray-level images which are not captured in colour, such as ultrasound images and their images enhanced through colouring. Clark and Leonhard translated the gray scale into a rainbow-like colour spectrum with respect to a physiological homogeneous brightness [6]. In X-ray images, constant-brightness as well as constant-saturation pseudocolouring extinguishes the relationship between X-ray intensities thus leading to an essential loss of diagnostic values. Lehmann, Kaser and Reppes [7] proposed a simple parametric equation for pseudocolouring gray scale images while maintaining their original progression of brightness, generating plenty colour changes to make use of the eye's capability to distinguish many colours at the same time. Rusev [8], used pseudocolouring for gray level to colour transformation in his design and realization of software module for visualization and analysis of digital images stored in DICOM. Silva et. al. [9] proposed a pseudocolour method to help visualize nodule structures and its initial result were promising.

The idea of applying pseudocolour to an ultrasound image is in widespread use to display motion information in Doppler ultrasound but almost new in displaying B-mode ultrasound. Czerwinski, R.N. et. al. [10] presented a

technique of enhancing linear features in B-mode ultrasound image by using a pseudocolour. The technique showed good results at improving the visual detectability of linear features. In clinical applications, the ability to display additional information without “corrupting” the original image information is important because the expertise of the ultrasound sonographer is highly specialized in analyzing images with a standard appearance. Demonstration showed a more precise characterization is possible with the coloured images.

The effectiveness in displaying gray level ultrasound images as colour images is examined and a pseudocolour enhancement technique for enhancing features in ultrasound ovarian image is presented. Hence, a pseudocolouring method is proposed which allows easy discrimination of texture information. The aim of this study is to evaluate the effectiveness of pseudocolouring ultrasound image in the diagnosis of ovarian cyst.

Much more visual contrast is noticeable in the colour images than in the gray level images, which consequently enable the viewer to better delineate the detail of the organ structure. A combination of this pseudocolouring method with other image enhancement techniques such as contrast stretching and seed based region growing is also introduced. The combination of the pseudocolouring approaches with the other image enhancement techniques can dramatically increase the information in ovarian ultrasound images.

The shape and intensity of the echoes depends on how dense the tissue is. Attention is given to delineate the anechoic and hypoechoic region with the other region. Its impedance between tissues can easily be determined. This paper also discusses the selection of colours and presents a scheme which uses the RGB

uniform colour space to select 256 colours for replacing the 256 gray scales used to represent the gray level image.

2. Ultrasound Interpretation of ovarian cyst

Two-dimensional ultrasound of the female pelvis has been established for several decades as the most reliable and effective way to image the uterus and ovaries and the surrounding structures.

Ultrasound is the primary imaging tool for a patient considered having an ovarian cyst. Findings can help define morphologic characteristics of ovarian cysts. Endovaginal ultrasound can help in a detailed morphologic examination of pelvic structures. Transabdominal ultrasound is more preferable than endovaginal ultrasound for evaluating large masses. However, it requires a full bladder [11].

Most of ovarian masses are simple cysts. Ultrasound is valuable in differentiating cystic from solid masses. Ultrasound criteria for a simple cyst and a complex cyst are shown on Table 1 [12,13,14,15]. Since conventional ultrasound image is in gray level, doctors have to be skillful in interpreting the image. Benign lesions are often associated with posterior enhancement, malignant lesions with posterior shadowing and simple cysts with relative posterior hyperechogenicity. Computerized analysis allows for an objective assessment of posterior acoustic shadowing which is an important factor in the discrimination of cysts from non-cysts. Accurate identification of lesion margin and shape is generally difficult in ultrasound images. The focus of the research presented in this paper is therefore to investigate the use of pseudocolouring features describing the lesion, extracted from two dimensional (2D) ovarian ultrasound images for the characterization of ovarian masses as either cysts or solid lesions.

Table 1 The criteria for a simple cyst and a complex cyst.

Characteristic	Simple Cystic	Complex Cystic
Shape of mass	Unilocular spherical	Multilocular (more than 1 compartment)
Internal Consistency	-No internal echo -Homogenous -Anechoic/hypoechoic (fluid) contents	- Internal echo (containing both a cyst, and solid component) - Heterogenous -Various echogenicity (ranging from anechoic to echogenic)
Definition of border	Well defined	Moderately well define
Common mass	-Functional ovarian cyst (follicular and corpus luteum) -Cystic Teratoma -Para-Ovarian	-Hemorrhagic cyst -Endometriomas -Ectopic pregnancy -Cystadenoma -Hydrosalpinx -Abscess

		-Teratoma (dermoid)
Uncommon mass	Serous cystadenomas, inclusion cyst	Polycystic ovary
Malignant potential	Low	Intermediate/High
Posterior details	Posterior hyperechogenicity or good acoustic enhancement	Posterior enhancement/shadowing

3. Ultrasound Image and Pseudocolouring

The basic aim of image enhancement is to highlight or enhance particular aspects of an image. Images such as an ultrasound image can be made more susceptible for interpretation by a doctor or sonologist. A new method of pseudocolouring ultrasound gray level images is proposed. In many applications, the human eyes are more sensitive to colour changes rather than to intensity changes [10,16,5]. Therefore, it is natural to encode the intensity of gray level images by using colour information. This process is called pseudocolouring. A pseudocolour enhancement technique is normally applied to a single band gray level image in digital image processing. It is considered an effective way of highlighting different but apparently homogeneous areas within an image by 'slicing' the range of grayscale values and assigning different colours to each of those slices. The technique utilizes the knowledge that gray levels (intensities) in the image represent the linear absorption coefficients of the elements in tissues and groups pixels with similar gray levels and hence similar absorption coefficients into a region, with colour representing the region. The colour assignment to each of the gray level section was chosen on a trial and error basis. Much more visual contrast is noticeable in the colour images than in the gray level images. The viewer can consequently demarcate the details of the organ structure in a much better perspective. Pseudocolouring allows easier discrimination of texture information.

Most pseudocolour techniques perform a gray level to colour transformations. The idea is to perform 3 transformations on a particular gray level and to feed these to the three colour inputs (RGB) of a colour monitor. The result is a composite image whose colour content depends on the gray level to colour transformations. The algorithm used to perform pseudocolouring is:

$$c(x,y) = T(f(x,y)) \quad (\text{Equation 1})$$

where $f(x,y)$ is a gray level image and $c(x,y)$ is a colour image. It is usually expressed in terms of its red, green and blue components $c(x,y) = [c_R, c_G, c_B]$. Pixels with low

values are assigned dark gray-levels and high pixel values are assigned bright gray-levels. The transformation function T produces a three-channel output [17, 4, 18, 9, 20].

Pseudocolouring is usually judged only subjectively. There are two different ways to find pseudocolouring transformations[4]. The first method is based on intensity quantization. L is the total number of gray level, $f(k,l)$ is the original intensity of the gray level image and N is the total number of region with different colour.

$$T(f(k,l)) = \begin{cases} c_0 & 0 \leq f(k,l) < f_1 \\ c_i & f_i \leq f(k,l) < f_{i+1}, \\ & 1 \leq i \leq N-2 \\ c_{N-1} & f_{N-1} \leq f(k,l) < L \end{cases} \quad (\text{Equation. 3})$$

Another modification of image intensity pseudocolouring is based on arbitrary image thresholding. In this case, a set of $N - 1$ thresholds f_i , region $i = 1, \dots, N-1$, is defined by the user. The transformation function takes the form [3]:

$$T(f(k,l)) = \begin{cases} c_i & \text{if } i \left\lfloor \frac{L}{N} \right\rfloor \leq (f(k,l)) < (i+1) \left\lfloor \frac{L}{N} \right\rfloor, \\ & i = 0, 1, \dots, N-2 \\ c_{N-1} & \text{if } (N-1) \left\lfloor \frac{L}{N} \right\rfloor \leq (f(k,l)) < L \end{cases} \quad (\text{Equation 2})$$


It must be noted that all transformations are point wise non-linear operator. This study concentrates on the second approach, which is arbitrary image thresholding pseudocolouring the ultrasound gray level image. The thresholding is chosen based on the echo pattern of ultrasound image. There are various approaches for assigning colour to gray-level images. Attention is given to delineate the anechoic and hypoechoic region with the other region such as moderately echogenic, echogenic and hyperechoic. Referring to Table 2, dark brown is assigned to regions 1 and 2, representing background or anechoic and hypoechoic regions. Yellow and white are assigned to regions 8 and 9 representing echogenic and hyperechoic regions. Colour tones (hue) between brown

and yellow were assigned to the other regions between region 2 and 8 representing moderately echoic or isoechoic tissue. Region 3 produced a darker image, which has less luminance than region 4 and so on. As the

gray level values increase from low to high value, this mapping produces colour varying from dark brown to light yellow.


Tables 2 (a) The range of gray level intensities for thresholding and associated colours to represent the echo pattern for Pseudo 1.

Region	The range of gray level intensity
1	$0 \leq F < 15$
2	$16 \leq F < 35$
3	$36 \leq F < 75$
4	$76 \leq F < 95$
5	$96 \leq F < 115$
6	$116 \leq F < 145$
7	$146 \leq F < 215$
8	$216 \leq F < 245$
9	$246 \leq F < 256$

Output Colour Table & Relevant Echo Pattern for Pseudo 1	
	<ul style="list-style-type: none"> Anechoic/ Hypoechoic Region Moderately echoic/ Isoechoic Region Echogenic/ Hyperechoic Region


Tables 2 (b) The range of gray level intensities for thresholding and associated colours to represent the echo pattern for Pseudo 2.

Region	The range of gray level intensity
1	$0 \leq F < 40$
2	$41 \leq F < 100$
3	$101 \leq F < 150$
4	$151 \leq F < 170$
5	$171 \leq F < 200$
6	$201 \leq F < 250$
7	$251 \leq F < 256$

Output Colour Table & Relevant Echo Pattern for Pseudo 2	
	<ul style="list-style-type: none"> Anechoic/ Hypoechoic Region Moderately echoic/ Isoechoic Region Echogenic/ Hyperechoic Region

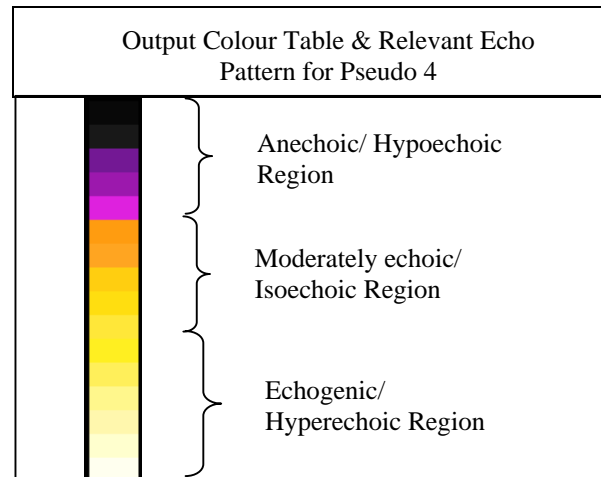
Tables 2 (c) The range of gray level intensities for thresholding and associated colours to represent the echo pattern for Pseudo 3.

Region	The range of gray level intensity
1	$0 \leq F < 14$
2	$15 \leq F < 24$
3	$25 \leq F < 34$
4	$35 \leq F < 49$
5	$50 \leq F < 69$
6	$70 \leq F < 99$
7	$100 \leq F < 129$
8	$130 \leq F < 159$
9	$160 \leq F < 199$
10	$200 \leq F < 256$

Output Colour Table & Relevant Echo Pattern for Pseudo 3	
	<ul style="list-style-type: none"> Anechoic/ Hypoechoic Region Moderately echoic/ Isoechoic Region Echogenic/ Hyperechoic Region

Tables 2 (d) The range of gray level intensities for thresholding and associated colours to represent the echo pattern for Pseudo 4.

Region	The range of gray level intensity
1	$0 \leq F < 14$
2	$15 \leq F < 24$
3	$25 \leq F < 34$
4	$35 \leq F < 49$
5	$50 \leq F < 69$
6	$70 \leq F < 99$
7	$100 \leq F < 129$
8	$130 \leq F < 159$
9	$160 \leq F < 199$
10	$200 \leq F < 256$



The darker shade of gray is mapped to brown while a lighter shade of gray is mapped to yellow. The absence of brown and an increase in yellow helps to emphasize a “shadow” in that region. The focus in this pseudocolouring method is to highlight the differences between anechoic and hypoechoic regions with anechoic and hyperechoic regions. Intensity or luminance value of the output or the colour image is increased such as the intensity or luminance of the input gray level image.

It is important to maintain the tone between hypoechoic region and echogenic region because an ultrasound image is interpreted based on the tone. For a 256 gray level image, the mapping is illustrated as in Table 2. Arbitrary image thresholding can be used to implement the transformation. Pseudo 2 uses the same concept as Pseudo 1, with a similar hue chosen to represent the echo pattern. On the other hand, Pseudo 3

and 4 emphasizes a different colour to represent anechoic and hypoechoic region compared to the other regions.

This pseudocolouring technique is demonstrated on an ultrasound image of ovarian cysts. Figure 1 (a) shows an ovarian cyst, which appears as a relatively dark region, whereas the surrounding solid tissues appear brighter. Figure 1 (b) is the histogram of the ovarian ultrasound image, which indicates that the gray level image is usually concentrated at the zero end of the spectrum. The results of pseudocolouring are shown in Figure 1 (c)-(f) for all types of pseudocolouring (Pseudo 1 – Pseudo 4), with transparent fluid represented by a dark colour, whereas solid tissues appear brighter. Using Pseudo 1 and Pseudo 2, dark colour represents the cyst and similar brighter colour represent posterior enhancement of ovarian cyst. While using Pseudo 3 and Pseudo 4, a dark colour represents the cyst and a different brighter colour represent posterior enhancement.

Figure 1 Gray level and pseudocolour ultrasound image of ovarian cyst

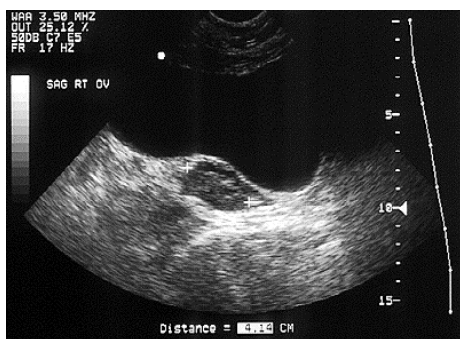


Figure 1 (a) Gray level image of ovarian cyst

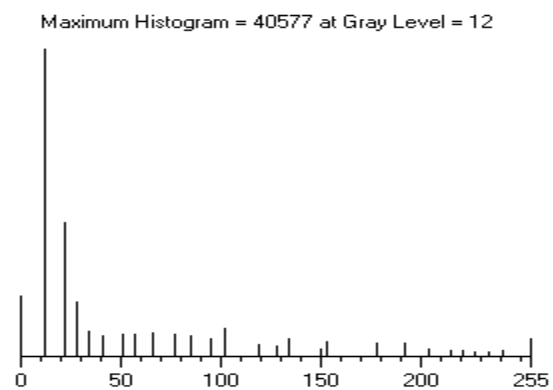


Figure 1 (b) Histogram of image (a)

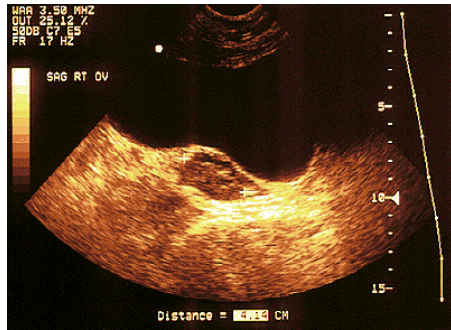


Figure 1 (c) Pseudo 1 of image (a)

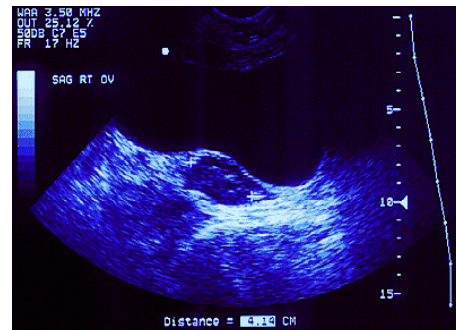


Figure 1 (d) Pseudo 2 of image (a)

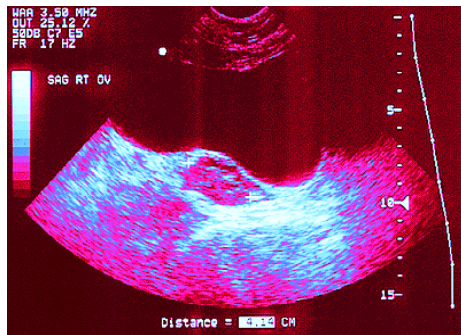


Figure 1 (e) Pseudo 3 of image (a)

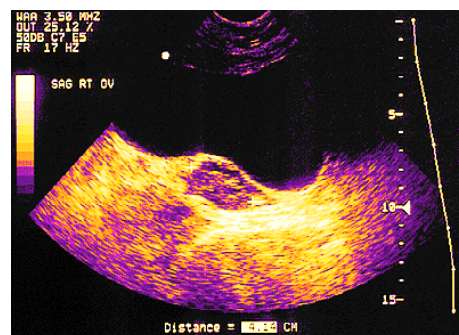


Figure 1 (f) Pseudo 4 of image (a)

4. Combination of Pseudocolouring with Other Image Enhancement techniques

An effective image enhancement method for ovarian ultrasound will provide better input not only for visual inspection by doctors or sonographers but also for medical imaging applications such as ovarian cyst border detection. Part of the goal of this study is to further enhance the image contrast while maintaining information.

Ultrasound images with less contrast should be pre-processed before the pseudocolouring method is applied. Contrast stretching can elevate the contrast, while region selection can highlight area of interest. The seed based region growing can segment the disease area and pseudocolouring can enhance particular differences of impedance between tissues. The combination of the image enhancement techniques such as contrast stretching, region selection, seed based region growing and the pseudocolouring approach can dramatically improve the contrast and provide more information in the ovarian ultrasound images.

The seed based region growing is a segmentation method to segment a region of interest (ROI). In the seed based region growing, a pixel in the region is used as a seed point and then all the similar pixels (spatially close

pixels sharing the same features, i.e. neighbors) are gathered together in the same region. The region growing method for defining ROI is based on gray scale difference. It has the potential to improve clinical diagnosis and research. Defining the ROI is one of the most important steps in characterizing the tissue since it forms the basis for all the subsequent steps.

A local rectangular region centered at the point is defined. If this rectangular satisfies a certain local homogeneity criterion, it is taken as the seed region. Otherwise, the region is contracted successively until the contracted region satisfies the homogeneity criterion. Once the seed region is determined in this way, the next step is to grow the homogeneous region by absorbing a thin rectangular adjacent side region, which has the same statistical properties as that of the current region. Figure 2 (a) is an ultrasound image of endometriomas, which appear as spherical lesions. Contrast Stretching applied to image 2 (a) is shown in Figure 2 (b). Referring to Figure 2 (c), the hypoechoic part is better segregated from the echogenic part through the use of pseudocolor. Blood clot, which is echogenic part of endometriomas appears as light brown.

Figure 2 Gray level image and processed image of endometriomas

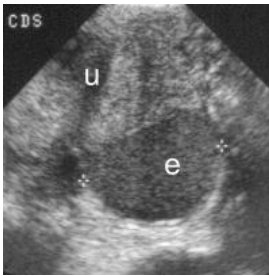


Figure 2 (a) Original image of endometriomas posterior uterus

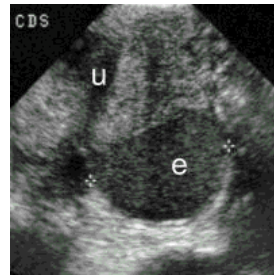


Figure 2 (b) Image 1 processed by Contrast Stretching

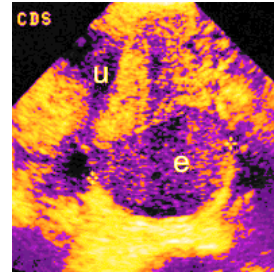


Figure 2 (c) Image 2 processed by Contrast Stretching and followed by pseudocolouring

For images containing multiple cysts as in Figure 3 (a), an ROI should be used to highlight the region, refer to Figure 3 (b), that possibly contain the cysts and to avoid the detection of edge outside the region when the seed based region growing is applied. The seed based region

growing that is used for thresholding contains a similar amount of pixels from the cysts and from the surrounding tissue. Figure 3 (c) shows multiple follicles, which appear as black bubbles. The anechoic portion is better demarcated from the echogenic part using pseudocolouring.

Figure 3 Gray level image and processed image of follicles cyst.



Fig. 3 (a) Original image of multiple follicles cyst

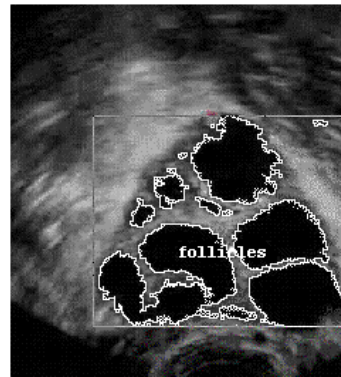


Fig. 3 (b) Processed image 2, with region selection and Seed based region growing edge detection

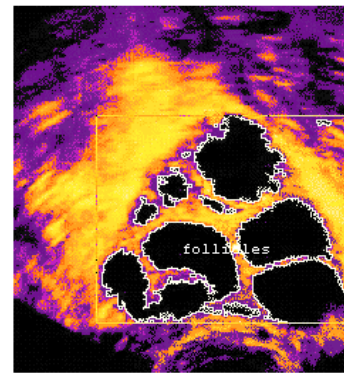


Fig. 3 (c) Processed image 3 with region selection, seed based region growing edge detection and followed by pseudocolouring

5. Conclusion

A method of pseudocolouring in ultrasound images has been proposed. The potential of the method was demonstrated using images of ovarian cyst. From the revealing demonstration, the result showed a more precise characterization is possible with the coloured images. The use of pseudocolour is a very promising technique to differentiate cyst from non-cyst region. The technique is effective not only for detection but also for subjective visual enhancement of images. In the context of image enhancement however, it may be of value to include the information, if the resultant images are more

easily interpretable. The models developed in this study can be used as part of a computer-aided-diagnosis system to characterize ovarian lesions. Computerized analysis of ultrasound images has the potential to increase the specificity of ovarian ultrasound and to aid in better characterization of cystic lesions. As the study is still at a preliminary stage, efforts are being done to implement the study further in clinical evaluation and assessment to demonstrate the usefulness of pseudocolouring.

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