Computerized Automatic Nasal Bone Detection based on Ultrasound Fetal Images Using Cross Correlation Techniques

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Abstract: - Recent study shows that fetal chromosomal abnormalities can be detected in early ultrasonic prenatal screening by identifying the absence of fetus nasal bone. The drawbacks of current method are operator dependent, observer variability and improper training. In particular, accurate nasal bone detection requires highly trained sonographers, obstetricians and fetal medicine specialists since the ultrasound markers may easily confuse with noise and echogenic line in ultrasound image background. We present a computerized method of detecting the absence of nasal bone by using normalized grayscale cross correlation techniques. Image preprocessing is implemented prior to cross correlation to assess the availability of nasal bone. The resultant threshold, bordering the absence and presence of nasal bone, is set to a value of 0.35. The accuracy of the developed algorithm achieved was, around 96.26 percent which promises an efficient method to recognize nasal bone automatically. The threshold can be further improved if a larger set of nasal bone ultrasound images are applied.

Key-Words: - Chromosomal abnormalities, nasal bone, cross correlation, ultrasound image, matching, trisomy

1 Introduction

There is extensive evidence that effective prenatal screening for major chromosomal abnormalities can be provided in the first trimester of pregnancy. Ultrasound screening in first trimester of pregnancy provides an effective way of screening chromosomal abnormalities (aneuploidy). Recent studies shows that assessment of particular ultrasound markers offer promising non-invasive method for fetal abnormalities detection, such as nuchal translucency, nasal bone, long bone biometry, maxillary length, cardiac echogenic focus and ductus venous [1] [10] [26]. American college of obstetricians and gynecologists has updated their guidelines and has recommended that all the pregnant women should be counseled about availability of screening tests for fetal aneuploidies [13]. By determining the risk in first trimester earlier reassurance for those with normal babies and safer termination for those with aneuploid fetuses, is possible.

In 1866 Down noted that a common characteristic of patient with trisomy 21 is a small nose. He led other investigators to study nasal bone as a criteria for diagnosis[12]. Absence of nasal bone has emerged as one of the more promising first trimester ultrsonographic marker of trisomy 21 after nuchal translucency (NT). Cicero and colleagues published the first large prospective trial of nasal bone assessment in a high risk population undergoing CVS to assess for aneuploidy [14]. They determined that absence of nasal bone during first trimester was associated with Down syndrome. Because of high likelihood ratio for Down syndrome with an absent nasal bone and similarly low negative likelihood ratio when nasal bone is present, the authors estimated that assessment of nasal bone would significantly improve the performance of first trimester ultrasonography for Down syndrome [15]. Therefore, assessment of fetal nasal bone improves the performance of first trimester screening for trismoy 21 [3]. R. Has et al. [4] had reported that the absence of fetal nasal bone has a high positive likelihood ratio for Down syndrome in the first trimester screening, and the presence of nasal bone may potentially lower the need for invasive testing.. F. Orlandi et al. [6] concluded that absence of the nasal bone can be used as a marker for abnormalities screening and they have demonstrated inclusion of nasal bone in current screening protocol along with nuchal translucency, free beta-hCG and PAPP-A, can achieve high detection at a very low false-positive rate [11].

Sonographic studies at 15-24 weeks of gestation report absent or short nasal bone in 65% of affected fetuses [5, 16-18]. In most studies that assess nasal bone at 11-13+ 6 weeks of gestation findings from postnatal and postmortem were confirmed; the nasal bone was not visualized in 60-80% of cases[2,19-21]. It shows difficulty to scan nasal bone during first trimester. However, review of images by an experienced operator

indicated that assessment may have been hampered either by poor magnification and unfavorable section or by untrained operator. As with screening based on NT, currently it is imperative that sonographers who undertake risk assessment by examination of fetal profile receive appropriate training and certification of their competence in performing such a scan. Reproducibility studies suggest that reproducibility of measurement is variable among groups and poor in some studies [22-24]. It is possible that learning curve for this measurement is much longer that for NT measurement [25]. Hence, fetal Medicine Foundation has promoted standardization in the assessment of nasal bone which should follow the following criteria;

1. Gestation should be between 11 - 13 +6 weeks. [14]
2. Image is magnified so that head and upper thorax are included in the screen.
3. A mid sagittal view of fetal profile is obtained with ultrasound transducer being held parallel to longitudinal axis of nasal bone.
4. In correct view there are 3 distinct lines; first 2 lines are parallel and proximal to forehead,resembles an "equal sign". Top line is skin and bottom line, which is more echogenic than underlying skin , represents nasal bone. A third line, which is almost in continuity with the skin but at a higher level, represents tip of nose.
5. When the nasal bone appears as thin line, less echogenic than the overlying skin, it suggests that the nasal bone is not yet ossified and is classified as being absent.

Efforts have been made by numerous investigators worldwide to try to find an approach for automatic detection of fetal parameters to reduce amount of human intervention, it will also reduce inter and intra-observer variability. M. Chen et al. [7] had investigated the measurement of nasal bone by using 3D volume ultrasound fetal data during early pregnancy. Acquisition of three dimensional volumes data were recorded in mid-sagittal plane and examined using multiplanar techniques but result showed that 3D measurement offers no advantages over 2D sonography. Among the other previous work done, on automatic fetal measurements, research topics are more focusing on automatic nuchal translucency thickness measurement. However, automatic detection of nasal bone has not been addressed by many authors.

In this paper, we presented an automatic method to recognize and detect the fetal nasal bone based on 2 dimensional ultrasound images using cross correlation techniques. Prior to assess the absence of nasal bone, several image preprocessing techniques were implemented to trace the position of nasal bone due to random shape and position of embryo in ultrasound images. Fig. 2 illustrates different location of nasal bone due to different position of fetus in ultrasound images and Fig. 3 displays each important step toward abnormalities detection.

The rest of this paper is organized as follows. In section 2, we describe the procedure of image acquisition, and the detection procedure of the nasal bone. The results of present method are shown in Section 3, and finally we draw some conclusions in Section 4. The ultrasonographic sagittal view of a fetus with nasal bone is shown in Fig. 1.

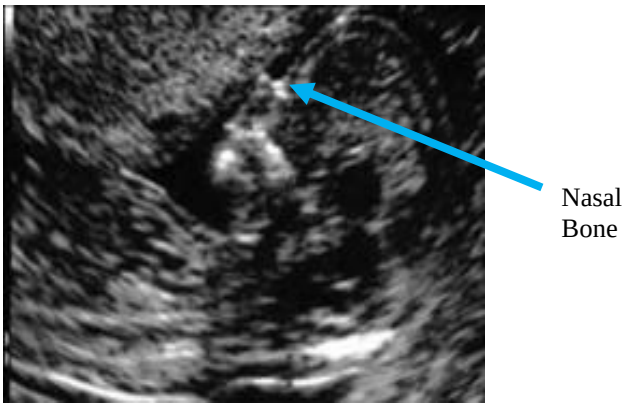


Fig. 1 Ultrasonographic sagittal view of fetus with nasal bone

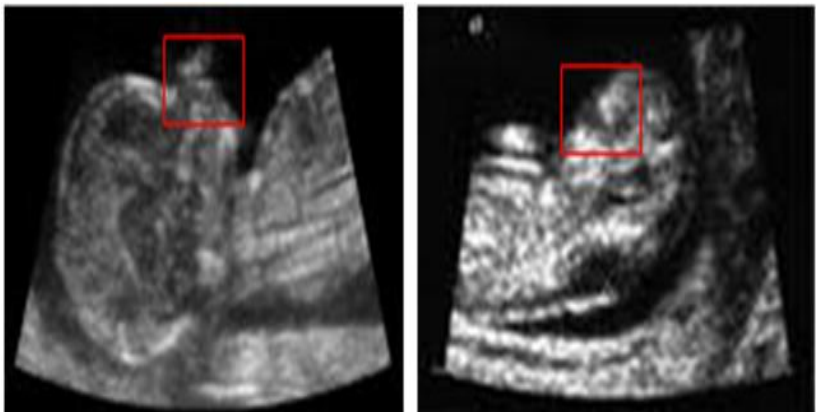


Fig. 2 Different location of nasal bone due to different position of fetus in 2 dimensional ultrasound images

2 Material and Methods

In this section, we describe the procedure of image acquisition, the characteristics of the nasal bone images and explain the recognition and detection procedure. The images of fetus with nasal bone were acquired using KNOTRON (Sigma 330 Expert) ultrasound machine with a 3.5MHz transabdominal transducer from Health Centre, Universiti Teknologi Malaysia. A mid-sagittal view of the fetal profile was obtained with the ultrasound transducer being held parallel to the longitudinal axis of the nasal bone. The angle of insonation is crucial because the nasal bone will not be visible almost invariably when the longitudinal axis of the bone is perpendicular to the ultrasound transducer. The images were saved into processing unit through our unique developed hardware in DICOM format. Fig. 4 below shows the block diagram of image acquisition from ultrasound machine to our developed hardware.

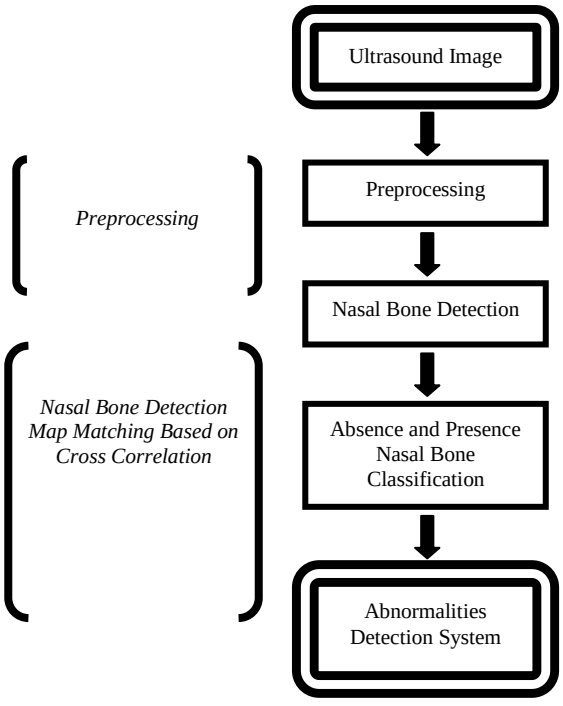


Fig. 3 Sequences of algorithm for each important processing

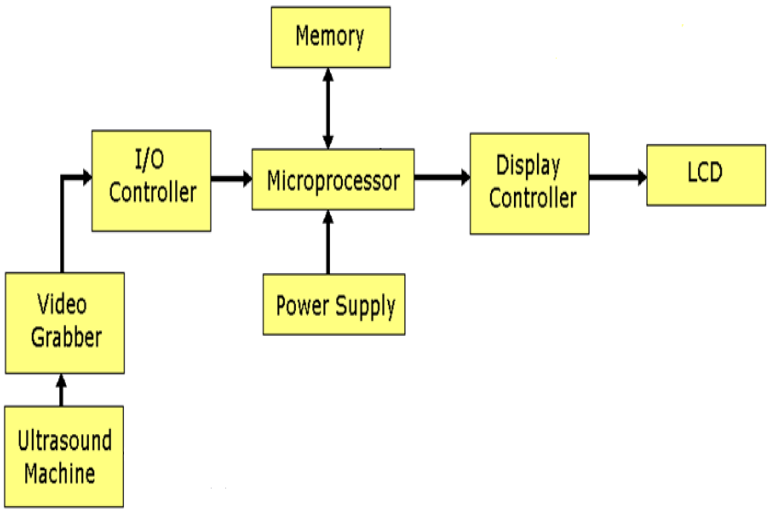


Fig. 4 Block diagram of image acquisition from ultrasound machine

2.1 Template matching

Template image matching has been a subject of research as early as the 80's. Since then, researchers have proposed several methods, battling against numerous demands from industries. The main difficulty in the present method is maintaining tolerance against various image distortions that can occur during image input. Such distortions include, but are not limited to, rotation, changes in size, linear and non-linear changes in brightness, perspective distortion, and noise of ultrasound images. Aside from accuracy and precision, efficiency is also an important element in constructing the full algorithm [9].

As industries involving the handling of small parts increase, intelligent vision robots are being demanded to replace human inspectors. As opposed to human inspectors, artificial intelligence provides tolerance to long work hours and high repeatability. This is especially true while we describes on medical doctors who are working in public general hospital with huge workloads per day. Consequently, there have been extensive studies in computer vision, especially in the field of template image matching. However, no effective algorithm that can match the human eye and brain has yet been discovered [9]. The algorithm introduced in present method can be regarded as an "upgrade" to what has already been discovered. It attempts to ease several difficulties that were present in previous matching algorithms.

2.2 Architecture of template matching with normalized grayscale correlation algorithm

Let's assume a given image S with matrix size P x Q and image T with matrix size M x N, where the dimensions of S are both larger than T. We proposed to call T as the Template Image $T_{i,j}$, and call the pattern in T as the Template Pattern, as well as calling S as the Search Image, $S_{i,j}$ as shown below,

$$\overline{S}_{i,j} = \frac{1}{mxn} \sum_{i=0,j=0}^{n-1,m-1} S_{i+x,j+y} \tag{1}$$

$$\overline{T} = \frac{1}{mxn} \sum_{i=0,j=0}^{n-1,m-1} T_{i,j} \tag{2}$$

Then, the output of S contains a subset image I where I and T are suitably similar in pattern and if such I exists; it will yield the location of I in S. The location of I in S will be referred to as the location of closest match, which will then been defined as the pixel index of the top-left corner of I in S.

$$\lambda(i,j) = \frac{\Im\left(S_{i+x+y} - \overline{S}_{i,j}\right)\left(T_{x,y} - \overline{T}\right)}{\sqrt{\Im\left(S_{i+x+y} - \overline{S}_{i,j}\right)^2 \Im\left(T_{x,y} - \overline{T}\right)^2}} \tag{3}$$

Where

$$\Im = \sum_{x=0,y=0}^{n-1,m-1}$$

and

$$0 \le i \le p-n,$$
$$0 \le j \le q-m$$

Let λ (*i, j*) be the correlation coefficient of *T* at location *i, j* of *S*, as defined in equation 3. The maximum value of λ is set to value 1. Therefore, whenever the coordinate integers of (*i, j*) be such that λ (*i, j*) obtained the highest correlation coefficient. The algorithm will return *i, j* as the "closest match" in *S*.

2.3 Image correlation

The normalized cross-correlation is calculated using equation 4 and will be displayed as a surface plot in 3D mode. The peak of the cross-correlation matrix occurs where the template image and target image are best correlated. However, algorithm must convert the image into grayscale before calculation of image correlation.

Equation 4 computes the normalized cross-correlation of the matrices template and target. The target matrix must be larger than the template matrix in order to make the normalization meaningful. Nevertheless, the values of template cannot all be the same. The resulting matrix contains the correlation coefficients, which can range in value from -1.0 to 1.0.

$$\gamma(u,v)=\frac{\sum_{x,y}\left[f_{x,y}-\overline{f}_{u,v}\right]\left[t_{x-u,y-v}-\overline{t}\right]}{\sum_{x,y}\left[f_{x,y}-\overline{f}_{u,v}\right]^2\sum_{x,y}\left[t_{x-u,y-v}-\overline{t}\right]^2} \quad (4)$$

Where f = image, t' = mean of template and $f_{u,v}$ is the mean of $f(x, y)$ in the region under the template.

After calculating the image correlation, the subsequent step of the developed algorithm is to convert the image correlation into surface plotting graph as shown in Fig. 5. Based on the graph, we are able to obtain the maximum value of the image correlation which will be used for image classification of absence and presence of nasal bone eventually.

3 Result and Analysis

In order to justify the performance of developed computerized algorithm, two different groups of testing images *k1*, *k2* were used. The group *k1* were randomly selected images with nasal bone screening from a consecutive group of registered patients by using the KNOTRON (Sigma 330 Expert) ultrasound machine, and the second group of images *k2* are the images with absent nasal bone, collected from Health Centre, Universiti Teknologi Malaysia. Some of the images with absent nasal bones were also taken from a few busy private maternity centres. The first group of testing catalogue *k1* consisting 100 numbers of ultrasound fetal images, where the second catalogue *k2* only contains 7 ultrasound images due to limitation of sources.

A thorough evaluation of the proposed method was carried out at the Medical Electronics Research Laboratory, Universiti Teknologi Malaysia, Malaysia. We ran the algorithm on both set of ultrasound images, with 640 x 480 sized ultrasound fetus images obtained by transabdominal ultrasonography. Table 1 lists the performance of tested algorithm on k_1 and k_2 images groups. The simulations result shows that it is capable of achieving as high as accuracy about 96.26 percent along with its promising reliability and consistent findings.

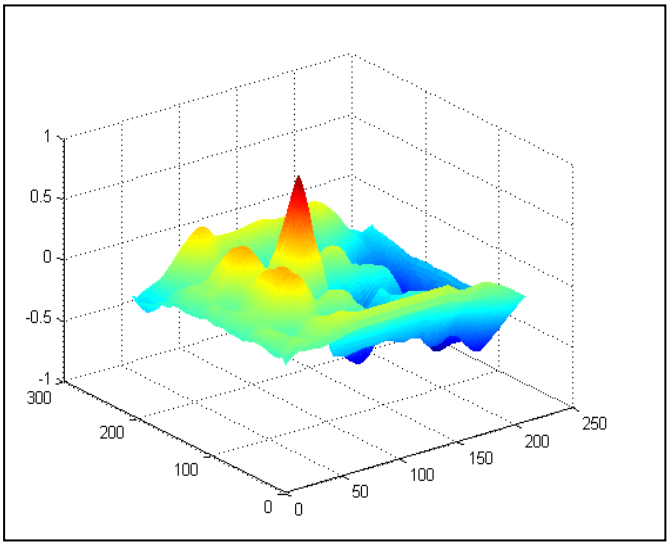


Fig. 5 Experimental sample result of image correlation in 3D surface plot

After all the images cross-correlation coefficient been calculated, the resultant surface plots were analyzed and the classified simulation showed that the peak of graph plotting was always below than the value 0.35, whenever an ultrasound image without nasal bone was tested. Fig. 6 shows the example image of comparison between absence and presence of nasal bone. Fig. 7 shows the experimental results for both groups of testing images.

Table 1 – PERFORMANCE OF CROSS CORRELATION TECHNIQUES FOR NASAL BONE DETECTION

Threshold	Group k_1	Group k_2	Accuracy
Correlation Coefficient > 0.35	97 true-positive (TP)	1 false-positive (FP)	96.26%
Correlation Coefficient < 0.35	3 false-negative (FN)	6 true-negative (TN)	
Total	100	7	

Accuracy = (TP + TN) / (TP + TN + FN + FP)

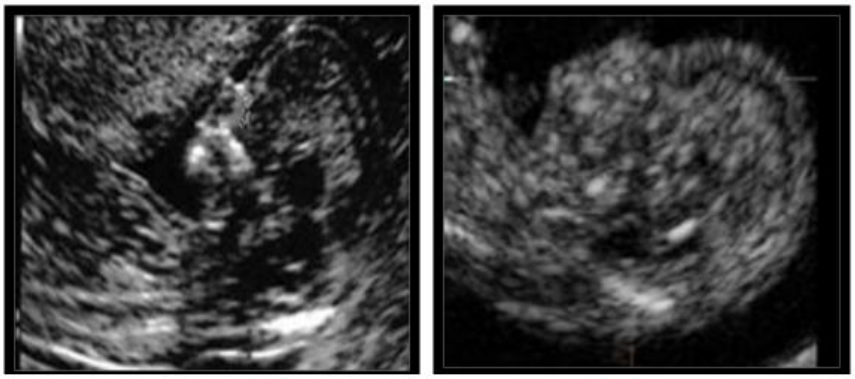
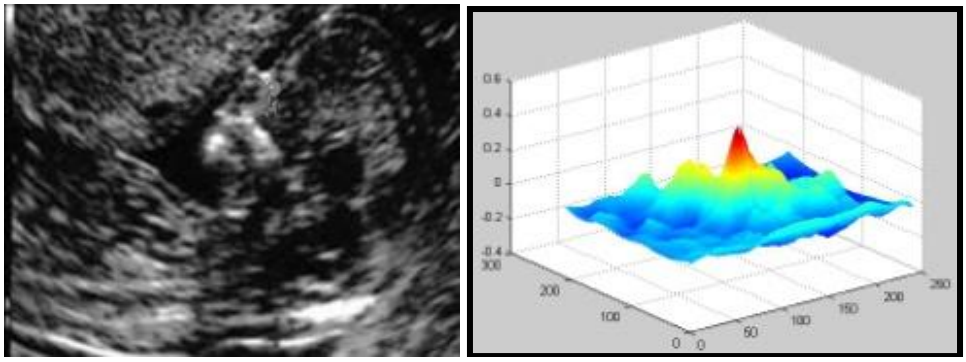
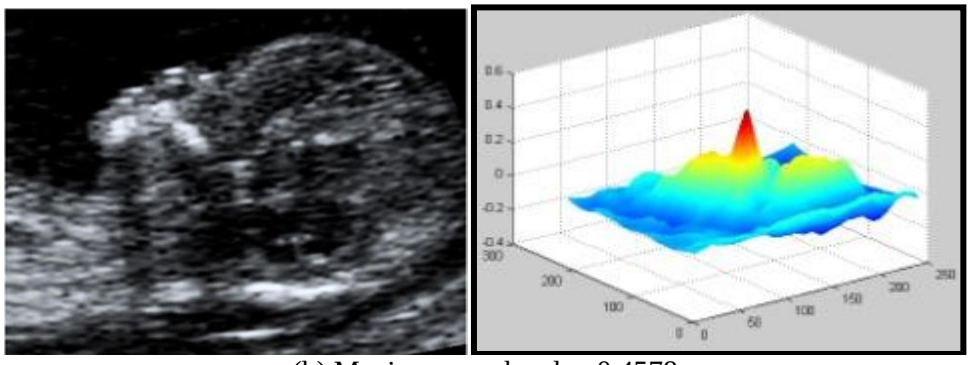


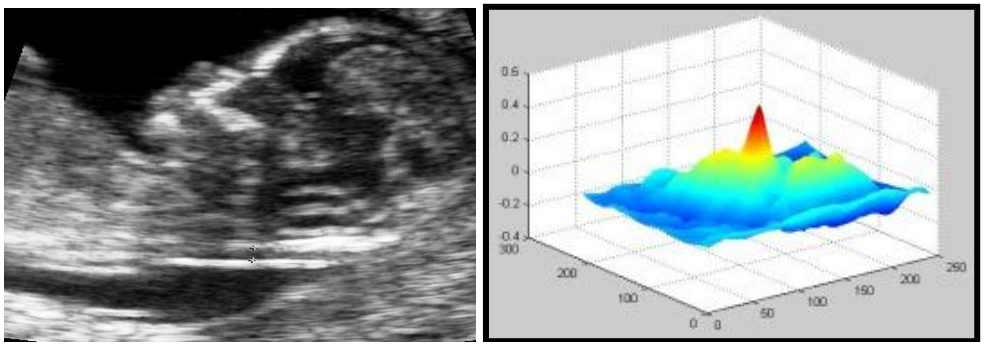
Fig. 6 shows the comparison of ultrasound sample images (a) with nasal bone (b) without nasal bone



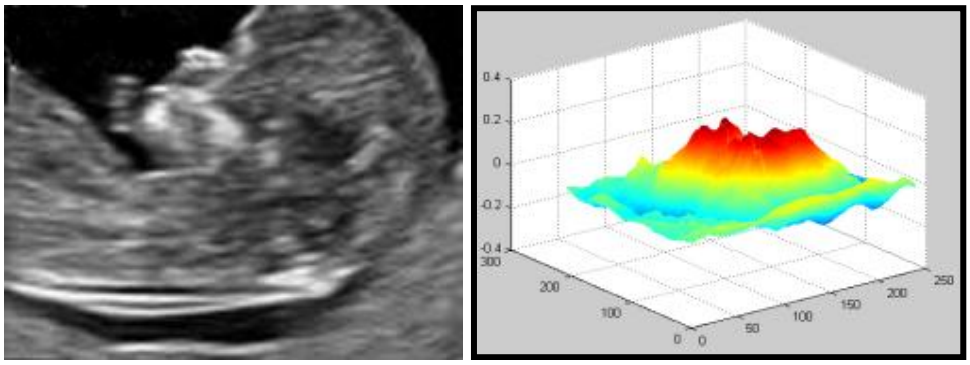
(a) Maximum peak value 0.5701



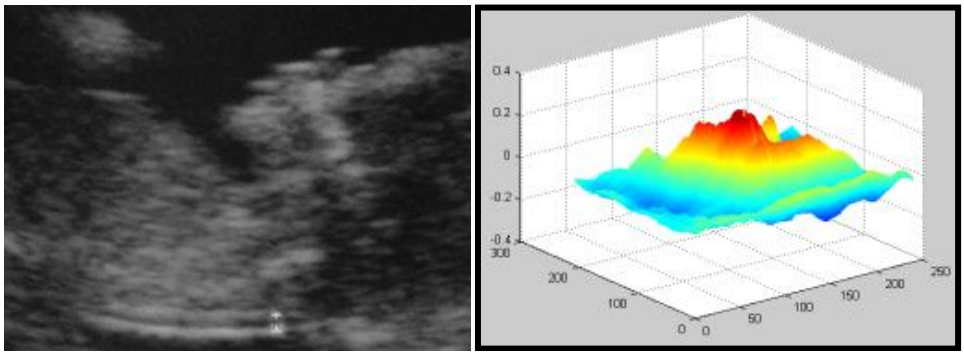
(b) Maximum peak value 0.4578



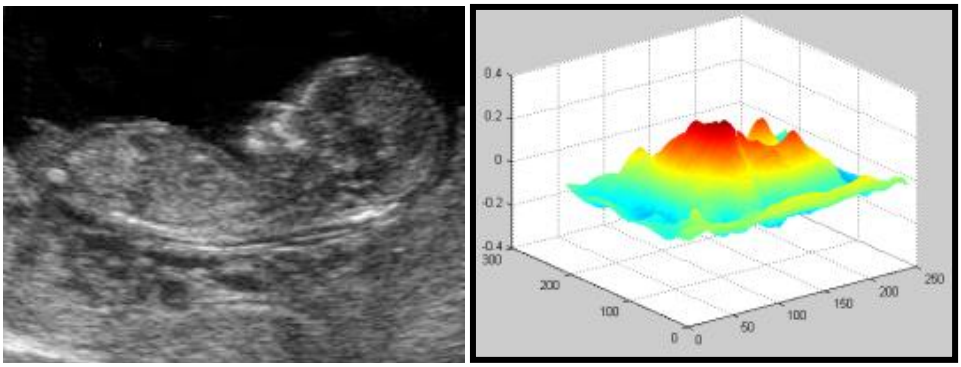
(c) Maximum peak value 0.5700



(d) Maximum peak value 0.2714



(e) Maximum peak value 0.3331



(f) Maximum peak value 0.3085

Fig. 7 shows part of the experimental results for images group k1 (a), (b) and (c), and images group k2 (d), (e), (f).

Based on the results from the experimental simulations, the developed algorithm will classify the threshold as value 0.35 as a border to distinguish the absence of nasal bone in a given ultrasound fetal images. In addition, we had also evaluated the calculated sensitivity with 97 percent (97 of 100), the specificity with 85.71 percent (6 of 7), the positive predictive value with 98.98 percent (97 of 98) and the negative predictive value with 66.67 percent (6 of 9) using the following equations. These results indicate the developed diagnostic model might be well recognized for detection of nasal bone.

$$Sensitivity = TP / (TP + FN) \quad (5)$$
$$Specificity = TN / (TN + FP) \quad (6)$$
$$Positive\ Predictive\ Value = TP / (TP + FP) \quad (7)$$
$$Negative\ Predictive\ Value = TN / (TN + FN) \quad (8)$$

However, the limitation of the current software is to acquire the correct scanning plane of two dimensional ultrasound fetal images. This is due to the nasal bone evaluation in 11-13+6 weeks is quite hard even for experienced people. Nasal bone is a structure which actually formed of two separate bones and only seen by ultrasonography after 10th gestational week. If it is not examined in an appropriate plane, it may be measured shorter or longer than normal or even it may be supposed that it does not exist. If the tested images are not in the true sagittal view or coincide in the suitable plane, ultrasound markers might not appears in appropriate position. This difficulty still remained unsolved in a few cases. To encounter the limitation mentioned above, we are investigating on real time scanning techniques to formulate state of the art algorithm in order to select the optimum plane of two dimensional ultrasound images in an automatic way.

4 Conclusion

We have proposed a method for automatic nasal bone recognition and detection based on normalized grayscale cross correlation techniques. From this method we are able to classify the absence and presence of nasal bone based on the obtained parameter value from the image correlation graph. The threshold bordering the absence and presence of nasal bone is set to a value of 0.35. The accuracy of the developed algorithm is achieved at least 96.26 percent which promises an efficient method to recognize nasal bone automatically. The threshold could have been further improved if a larger set of nasal bone ultrasound images were applied. Findings showed that the system is able to provide consistent and reproducible results.

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