Int. J. Nonlinear Anal. Appl.
Volume 12, Special Issue, Winter and Spring 2021, 1573–1583
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2021.5830

Ultrasound image based fully-automated nuchal translucency segmentation and thickness measurement

Kalyani Chaudhari[a,], Shruti Oza[b]

[a]*Electronics Engineering, Bharati Vidyapeeth (Deemed to be University) College of Engineering, Pune, Maharashtra, India, 411043, 0000-0002-7556-9707*
[b]*Electronics Engineering, Bharati Vidyapeeth (Deemed to be University) College of Engineering, Pune, Maharashtra, India, 411043, 0000-0001-5527-4031*

(Communicated by Madjid Eshaghi Gordji)

Abstract

The nuchal translucency (NT) detection and thickness measurement is a milestone in the prediction of the abnormalities in addition to chromosomal disorders in a fetus in ultrasound imagery. Nuchal translucency is an accumulation of fluids just at bottom of the foetal neck which is closely associated with chromosome abnormalities with cardiac arrest within the pregnancy period of the first trimester. At the hospital, the sonographers manually estimate the thickness of the mid-sagittal plane of nuchal translucency, which is a significant marker for prenatal screening. Such a conventional process done by a technician is quite time-consuming and requires a skilled technician. Within this methodology, an automatic NT detection method based on SIFT keypoint and GRNN is proposed in the mid-sagittal plane. This Non-invasive approach is crucial not just for the assessment of NT, as well as for the detection of extreme deformities and the identification of high-risk pregnancies. The proposed method is tested on a large image dataset which shows that the proposed technique has better accuracy than well-known state of the art methods. The proposed SIFT and GRNN based method have an error of 0.02 which is very less compared to the SVM, ANN, NB and KNN.

Keywords: GRNN, Nuchal translucency, NT, SIFT

Email addresses: kalyani4sp@gmail.com (Kalyani Chaudhari), Skoza@bvucoep.edu.in (Shruti Oza)

Received: August 2021 *Accepted:* Novamber 2021

1. Introduction

Ultrasound imaging is the most popular non-invasive technique to assess multiple abnormalities throughout reproductive phase. Leading to the contactless potential of Medical ultrasound, this is commonly seen in treatment mostly during whole pregnancy cycle. In order to test for unique markers to classify suspected genetic disorders in fatal, the first trimester ultrasound tests have vital knowledge of the entire progression of pregnancy [20]. The sonographic presence of intramuscular liquid deposition behind the fetal neck is known as nuchal translucency [13].The ordinary liquid intramuscular area between both the back of a fetal skin and the overlying skin is referred to as nuchal translucency (NT) [12]. The maximum distance between its superior and inferior high-intensity margins is known as NT thickness. It exists only as dark field. The nuchal translucency term was invented by a visionary in the study of prenatal trisomy 21 at the Fetal Medicine Foundation named as Professor Nicolaides [9] Nuchal translucency is an accumulation of fluids just at bottom of the foetal neck which are closely associated to chromosome abnormalities with cardiac arrest within pregnancy period of the first trimester of. At hospital, the sonographers manually estimate the thickness in mid-sagittal plane of NT, which is a significant marker for prenatal screening. Pathological deposition of fluids in the nuchal region (oedema and cystic hyqromas) observed mostly in second and third trimesters during pregnancy is associated with several chromosomal anomalies [1, 14]. Nuchal fluid during first trimester is analysed to determine the possibilities of chromosomal discrepancy in the respective period [15]. Such conventional process done by technician is quite time-consuming and which requires skilled technician. NT is observable and it can be determined through ultrasound imaging among 11 weeks and 14 weeks of pregnancy [22]. Expanded NT is associated with numerous fetal chromosomal and nonchromosomal discrepancies. There seems to be rising evidence of excessive NT thickness during pregnancy's first trimester is affected by various fetal structural discrepancy, genetic disorders, heart problems, and poor perinatal conditions such as miscarriage and intrauterine death [23, 3, 19]. Consideration should be given to the development of a reference value of nuchal translucency related to crown rump length in the first trimester in order to determine an acceptable cut-off threshold for evaluation of raised NT thickness related defects. As a result, chromosomopathies can be associated with increased Nuchal translucency thickness, and a range of pathologies induced by chromosomic disorders are associated with Down syndrome (trisomy 21), Edwards syndrome (trisomy 18), Patau syndrome (trisomy 13), and Turner syndrome (gonadal dysgenesis), as well as other heart defects such as omphalocele or diaphragmatic hernia.

Since the 1990s, NT has been the subject of a rigorous study in the pregnancy first trimester, after noticing a linkage among its thickness as well as the occurrence of chromosome discrepancy, the higher the thickness of a translucent, the greater the chance of abnormalities in fetus. Along with an approach to automatic NT detection, an assessment with the help of emerging technology makes it possible to strengthen NT thickness measurements since it solves the complexities involved in manual assessments. Non-invasive tool is crucial not just for assessment of NT, as well as for the detection of extreme deformities and the identification of high risk pregnancy [4].

Paper is organised as follows: Section 1 review the well known methods in the current field. Section 2 states the background of the NT detection and measurement. It also focuses on the challenges in this field. Section 3 gives the detail introduction of methodology for Head detection using SIFT and GRNN .It also describes the further procedure for NT thickness measurement. Section 4 summarizes the experimental results. Section 5 Conclude the research.

2. Literature survey

The width of a NT can be determined from its initial week of gestation, Thus it increases along with the development of the foetus, the time between the eleventh and thirteenth weeks has to be the period wherein NT achieves its full thickness. The NT sonography area tends to be nothing more than a dark fringe or an anechogenic region surrounded with two small, hyper-echogenic zones. Clinicians found a correlation between the size of the NT and the prevalence of chromosomal anomalies and other abnormalities: the wider the NT, the more likely the foetus would have some sort of abnormality.

Down syndrome, Edwards Syndrome, Patau Syndrome and Turner Syndrome are a few of the disorders affecting the foetus. Down syndrome or Trisomy 21 is known as a serious and widespread chromosome abnormality appearing almost once in every 800 to 1000 live births and rises in risk with maternal age. Affected infants are likely to experience with serious mental disorders and are at higher risk of physical disorders, especially in the heart, digestive tract, ears and eyes.

Traditionally by NT thickness is measured by using electronic callipers which is placed in the middle of two echogenic lines displayed on the screen by the technician. Bernardino F et.al. [2] Proposed in a semiautomatic manner, increasing the method's reproducibility. By selecting the NT manually further NT measurement is carried out using edge detector such a Sobel and canny. However by using calliper to manual tracing of these two echogenic lines contains much errors and variable opinions. As this images contains large speckle noise, which makes difficult to select markers. Lee Y et.al [24] proposed semiautomatic approach using which contains dynamic programming. Also border noise is also eliminated using coherence-enhancing diffusion filter.

P. Perona et.al [18] suggested scale-space diffusion process to encourage intra region smoothing rather than inter region smoothing. This approach enhances the region boundaries thus the global information can be successfully exploits. S. Nirmala et.al. [18] implemented The NT area is segmented utilizing mean shift analysis as well as canny, and the precise thickness is measured utilizing blob processing.

Y. Deng et.al [7] proposed automatic scheme to predict the thickness NT thickness. They estimate the edge map using morphological filtering and then using gradient vector flow snake contour is extracted. G.Sciortino et.al. [16] present the full automatic detection approach NT as well as to analyze its thickness which is consist of wavelet and multi resolution analysis. This method is tested on 382 frames of midsagittal plane from real time acquired ultrasonic videos.

3. Methodology

Background:

Most of the Previous study detects the NT manually [11, 17]. Some later research detect NT using Hough transform and Morphological Operations [10].This Technique are restricted to special anatomy , thus making use in real time little bit difficult. Also, Such technique is shape and size dependent. Active contour based biparietal diameter and head circumference detection is also proposed in literature [5]. but such techniques are very slow and less robust against image rotation. Also ultrasound background variations and imaging artefacts makes a challenging for detection. One of the well known supervised techniques uses SVM for NT, Body and Head detection [6]. But this technique is also unable to handle the slight change in rotation. This method uses coarse features for detection.

A. Detection of NT and fetal head

This section is used to estimate the probability of detecting the foetal head as well as the NT area. The reliability of the design is accomplished by using SIFT features to explore spatial relations and multi-resolution hierarchies. In this scenario, the location of the NT area is predicted to be based on its most appropriate candidate key points. Global patterns are better observed at rough resolution as well as provide local detection constraints for finer resolution. This reduces the search space for local detection, which improves reliability because most of the image regions are almost never addressed. In contrast, the computational speed increases resulting in reduced objective function.

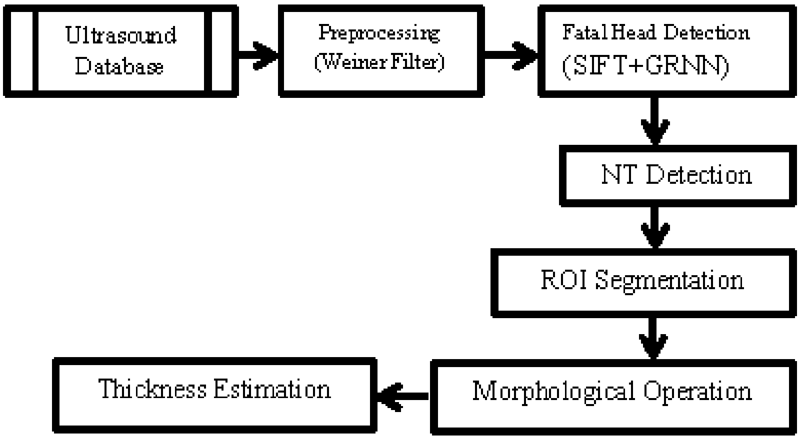


Figure 1: Proposed architecture

SIFT Feature:

The SIFT features are local and focused on the existence of the foetal head at specific areas of interest and are invariant to the scale and rotation of an image. These are indeed resilient to changes in brightness, noise, and subtle changes in perspective. These are indeed highly distinctive, fairly straightforward to retrieve and permit accurate head detection.

General Regression Neural Network (GRNN):

Generalized neural regression network is some kind of supervised neural forward feed network that drops under the class of probabilistic neural network. Suggested a generalised neural regression network (GRNN), a technique that makes use of neural networks to define nonlinear systems control and includes one-pass learning [21]. The strength of GRNN would be that it "learns" with a supervised manner through the dataset and therefore can generalize with instances as quickly as they are estimated [21]. This means that The use of GRNN is useful because of its capacity to converge to an underlying function with a few training dataset required. The GRNN have four layers. They are namely input layer, pattern layer, summation layer and output layer as shown in figure 1. The input neurons of input layer are simply distribution neurons, and cover all measurement variables x to all of the neurons available in the second layer which is pattern layer. Pattern layer is a first hidden layer of the GRNN. The numbers of neurons available in this layer are equal to the number of training samples available in training data set. The output of pattern layer gives distance between input patterns and stored one, whereas each neuron act as training pattern. Third layer is a summation layer which has two neurons, one neuron is for denominator summation which sums the weight values within each hidden neuron, and the numerator summation unit sums up the weight values multiplied by a real expected value with each hidden neuron. The output layer is fourth layer which receives the two outputs from hidden layer simply divides them to provide predicted output.

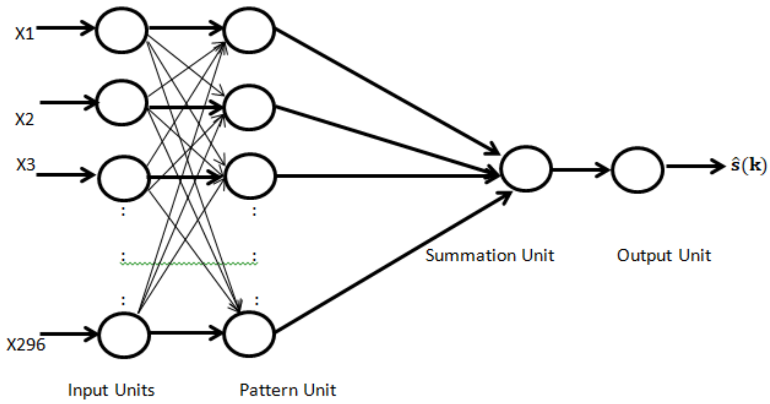


Figure 2: GRNN Architecture [8]

After pre-processing, SIFT features are extracted from image. These extracted features form the input feature vectors to the neural network used for fatal Head Detection. All extracted features are concatenated and used for GRNN training. GRNN is trained with fatal head by using 400 samples from our database. Trained model is used for the testing purpose. GRNN model have 100 input neurons, 100 neurons in hidden layer and 1 output neuron. The normalized radial basis function is used for training purpose. GRNN is a type of probability based neural network, which is most widely used in various issues such as prediction, control, plant process modelling or general mapping problems. As GRNN is a radial basis function (RBF) neural network variation which possesses the ability to learn in one pass, it converges very easily to the subjacent regression surface. It is renowned for its capability to train rapidly to solve all regression problems. It operates by calculating how far from the patterns in the training set to a given sample pattern is. The GRNN have four layers namely input layer, pattern layer, summation layer and output layer as shown in figure 2. The input layer receives the input signals, and with the training data set, the pattern layer performs the necessary mapping of the applied input data. For the GRNN, in the hidden layer, the number of neurons is usually equal to the number of patterns in the training set. With appropriate interconnection weights, the outputs for the nodes of the pattern layer are added together at the summation layer before which they undergo multiplication operation. The nodes of output layer deliver the necessary outcomes on the input dataset applied. For any set of N inputs, the GRNN will estimate the value of M in less amount of time defined by the propagation time. Propagation time is the time taken by the network to pass the input through it. M is assumed to be the estimated $\hat{\mathbf{s}}(\mathbf{k})$ of the desired signal $\hat{\mathbf{s}}(\mathbf{k})$. Whereas N represents values of the input feature vectors from input nodes, as can be seen in Fig.1b. GRNN estimates the estimated M (N) (i.e.$\hat{\mathbf{s}}(\mathbf{k})$) as follows.

$$M(N) = \frac{\sum_{i=1}^{n} M_i exp\left(\frac{-D_i^2}{2\sigma^2}\right)}{\sum_{i=1}^{n} exp\left(\frac{-D_i^2}{2\sigma^2}\right)} \tag{1}$$

$$D_i^2 = (N - N_i)^T.(N - N_i) \tag{2}$$

The σ is the smoothing factor for GRNN, and n is the number of input data samples. Choosing a smoothing factor is really essential. The large value of σ improves the capability of the network to generalize, while small value of σ reduces the ability of the network to generalize. (The larger the value of σ smoother is the function approximation and vice versa). Estimate $M(N)$ can be seen as a ratio of the summation of all the perceived values M_i, where each perceived value is measured to its exponential rate by its Euclidean distance from N. The 'newgrnn' function is used to create the GRNN in the MATLAB environment. In this research work GRNN inputs are the derived features from a reverberant signal frame that constitute the input features of the vectors x_1 to x_m. In contrast, the output of GRNN represents the estimated image signal $\hat{\mathbf{s}}(\mathbf{k})$ as shown in figure 3.

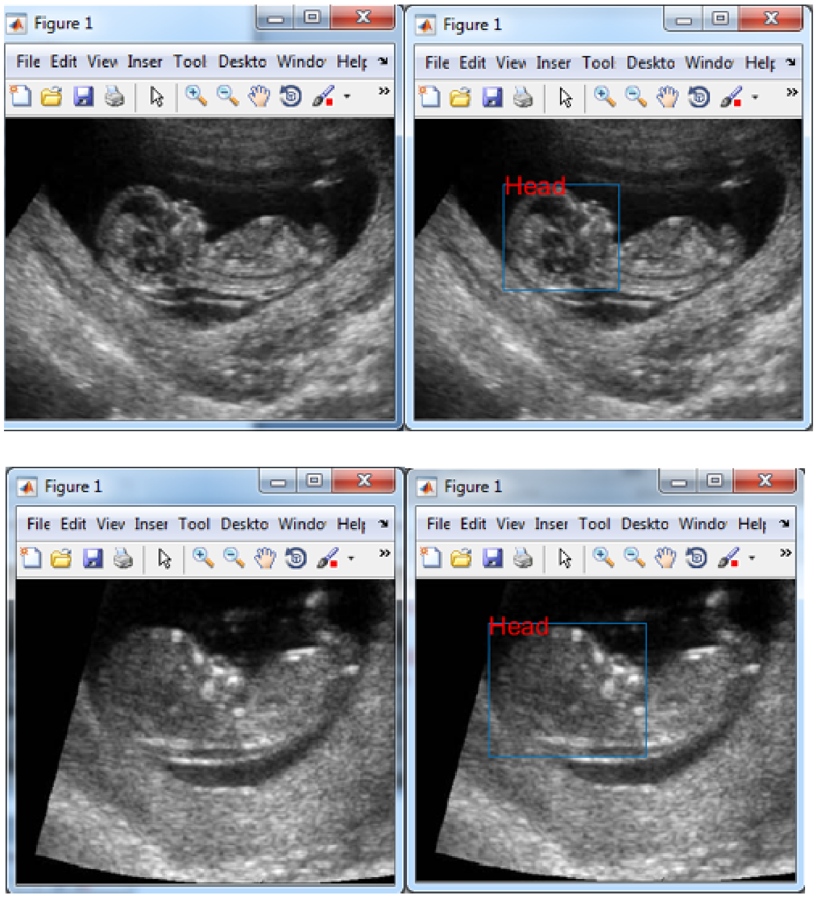


Figure 3: Input Ultrasound image and fetal Head detection

Above figure 3 shows the input image on the left side and on the right side Head detection results is displayed. This image is then search for keypoint from the trained head images. After getting large correlation, head is marked.

B. NT Measurement

In Ultrasound image faces is always upwards and head is on the left side of the image. Once the nuchal region has been recognised, the attention is on the nuchal translucent as well as the two regions that define it. Often in ultrasound imagery NT images do not have well defined edges and the intensity of these images plays a key role. Occasionally, the intensity is unexpectedly changes as a result of the Speckle noise.

In above figure 4, after detection of fetus head, NT is just below the head bounding box is taken as ROI. In this ROI thresholding and morphological processing is done. In morphological processing small noise opening and NT area filling is done.

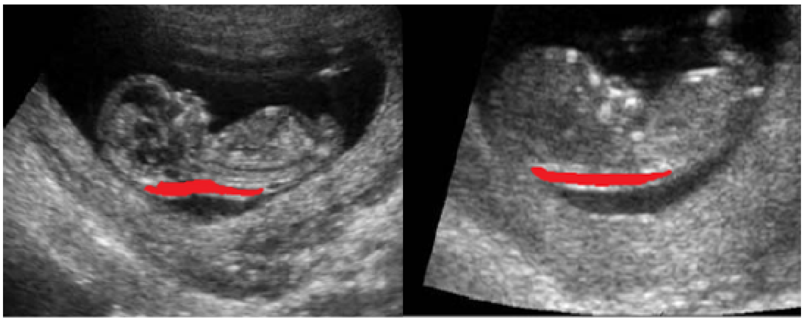


Figure 4: NT Detection

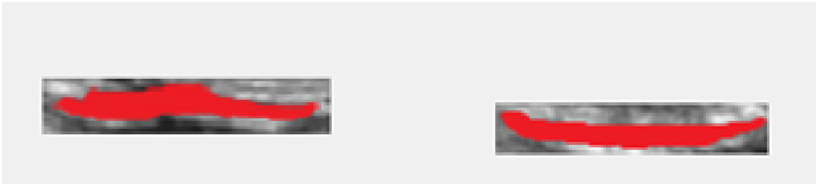


Figure 5: NT ROI Segmentation

In figure 5 NT ROI segmentation is shown. NT area is shown using red color. After getting segmented ROI, vertical pixel counting is done to estimate the NT thickness. X axis shows the NT ROI pixels and y axis shoes their pixel count which is our NT thickness in pixel. After Getting pixel count, those count is converted to original scale using reference chart of pixel to mm.

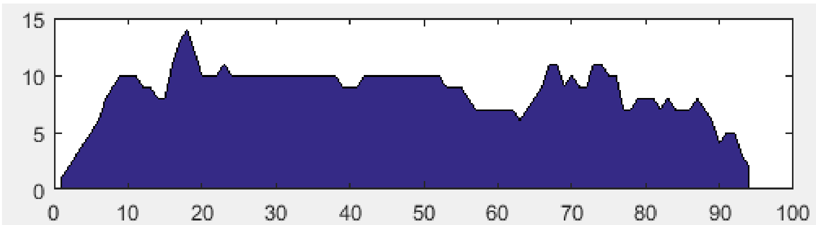


Figure 6: Segmented N ROI and Thickness plot

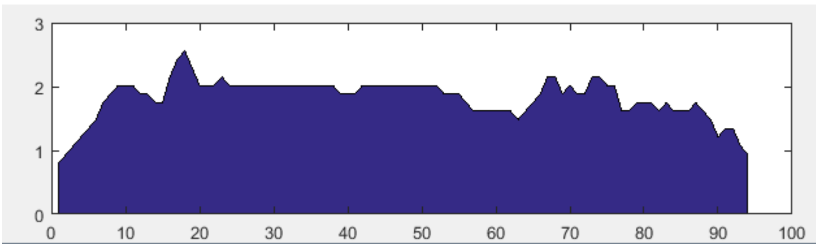


Figure 7: Thickness plot mapped to original scale (mm)

4. Experiments

Proposed method is tested on 500 images collected from various hospitals. This all images are of first trimester exams. Due to fetal activity, NT ultrasound images vary widely during screening.

All the images are in DICOM format. Those images are then converted to PNG format using DICOM reader tool. After converting those images they are converted to 512 × 512 size for further processing. In ultrasound image fetal head and NT ROI is labelled by technician for training of the GRNN.NT thickness is measured manually for validation of the proposed result.

Table 1: Proposed method maximum NT thickness measurement

	Measured MNT	Automatic MNT	Error
Proposed	2.89	2.87	0.02
SIFT-SVM	2.89	2.67	0.22
SIFT-ANN	2.89	2.81	0.08
SIFT-NB	2.89	2.67	0.22
SIFT-KNN	2.89	2.45	0.44

Above table 1 shows the comparison of the maximum NT measured manually and Automatically. second column shows the manual NT measured and third column shows estimated automatically. The last column shows the error between manual measured and the automatically estimated.

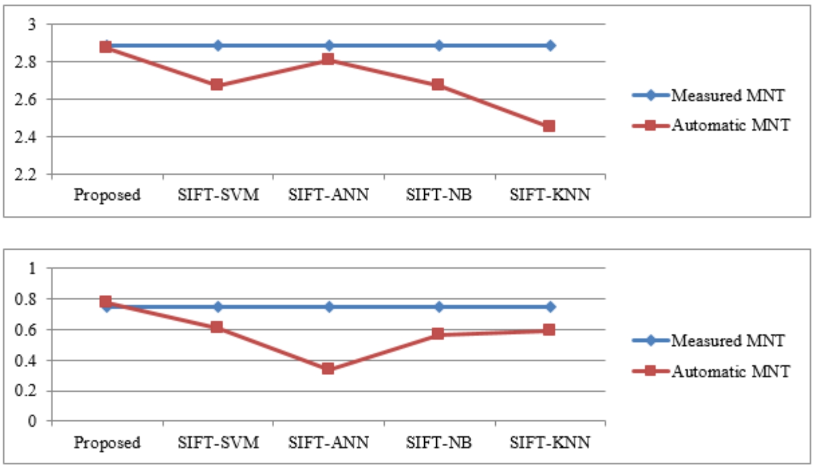


Figure 8: (a):Comparative analysis of the proposed NT thickness with well known methods.(b): Proposed Method Maximum and Minimum NT Thickness measurement.

Figure 8(a) shows the comparative analysis of the proposed NT thickness with well known methods. Proposed methods predicted thickness is close to the manual measured thickness.

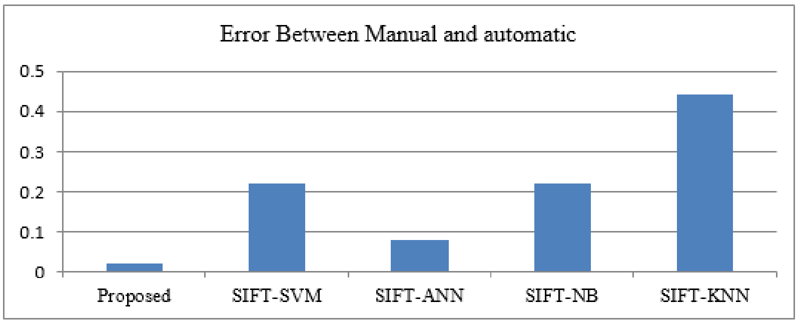
Figure 8(b) shows the error plot of proposed and rest of the method. Proposed method has less error of 0.02.

Table 2: Proposed Method minimum NT Thickness measurement

	Measured LNT	Automatic LNT	Error
Proposed	0.75	0.77	-0.02
SIFT-SVM	0.75	0.61	0.14
SIFT-ANN	0.75	0.34	0.41
SIFT-NB	0.75	0.56	0.19
SIFT-KNN	0.75	0.59	0.16

Above table 2 show the comparison of the minimum NT measured manually and automatically.

Second column shows the manual NT measured and third column shows estimated automatically. The last column shows the error between manual measured and the automatically estimated.



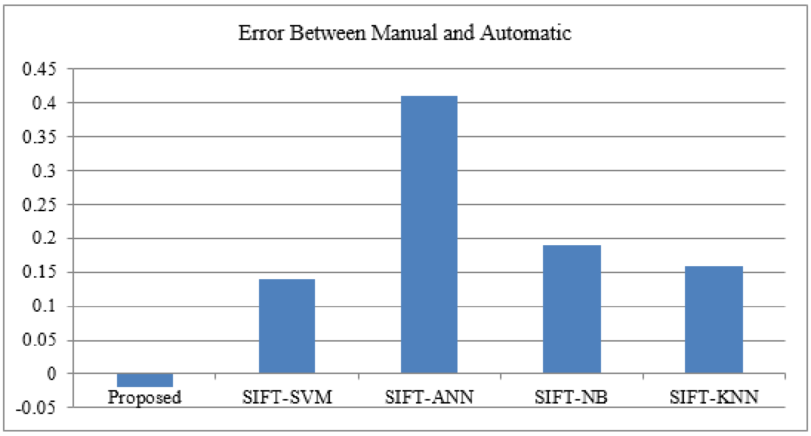


Figure 9: (a) :Comparative analysis of the proposed NT thickness with well known methods, (b): Comparison of Error Between Maximum NT thickness measure manually ant automatic

Figure 9(a) shows the comparative analysis of the proposed NT thickness with well known methods. Proposed methods predicted thickness is close to the manual measured thickness. Figure 9(b) shows the error plot of proposed and rest of the method. Proposed method has less error of 0.02.

5. Conclusion

Ultrasound imaging is the most well known non-invasive way to assess various diseases throughout reproductive phase. Ultrasonography is done through early pregnancy for dating, estimation of the number of foetuses, estimation of expose vulnerabilities and, increasingly, assessment of the foetus, including measurement of nuchal translucency (NT) thickness. Nuchal translucency is an accumulation of fluids just at bottom of the foetal neck which are closely associated to chromosome abnormalities and early cardiac arrest in the first trimester of pregnancy. In the hospital, the sonographers manually estimate the thickness of NT in the mid-sagittal plane, which is a significant marker for prenatal screening. Such conventional process done by technician is quite time-consuming and which requires skilled technician. In this paper fully automatic NT detection approach is presented. Firstly, fatal head is detected using SIFT features. Fetal head is considered as a primary keypoint to locate NT Region. Then NT region is locally refined and then segmentation is carried out. The presented contribution incorporates a fully automated technique to Support physicians in the assessment of certain significant chromosomal Impairment. Proposed method is tested on large image dataset which shows that proposed method have better accuracy than well known state of the art methods. Proposed method has error of 0.02 which is very less compared to the SVM, ANN, NB and KNN.

6. Discussion

Ultrasound imaging is the most well known non-invasive way to assess various diseases throughout reproductive phase. Nuchal translucent (NT) thickness measurements have recently been suggested as part of regular ultrasound scanning for early screening of chromosome defects mostly during late first trimester of pregnancy. Nuchal translucency is an accumulation of fluids just at bottom of the foetal neck which are closely associated to chromosome abnormalities and early cardiac arrest in the first trimester of pregnancy. In addition, the ultrasound image evaluation is reproducible, non-invasive and it does not Presents the risk of complications or maternal injury. In the hospital, the sonographers manually estimate the thickness of NT in the mid-sagittal plane, which is a significant marker for prenatal screening. Such conventional process done by technician is quite time-consuming and which requires skilled technician. Along with an approach to Automatic NT detection, an assessment with the help of emerging technology makes it possible to strengthen NT thickness measurements since it solves the complexities involved in manual assessments. Non-invasive tool is crucial not just for assessment of NT, as well as for the detection of extreme deformities and the identification of high risk pregnancy. Proposed method is tested on large image dataset which shows that proposed method have better accuracy than well known state of the art methods. Proposed method has error of 0.02 which is very less compared to the SVM, ANN, NB and KNN.

7. Acknowledgement

This paper would not have been possible without the contributions of numerous researchers in this field. I would like to thank all of them – especially Dr.Sonali Chaudhari (Infertility Specialist, Gynaecologist, Obstetrician) for her help and Apex Diagnostic Centre, Pune for giving database and kind advice.

8. Funding source

We don't have any financial support.

References

[1] G.B. Azar, R.J. Snijders, C. Gosden and K.H. Nicolaides, *Fetal nuchal cystic hygromata: associated malformations and chromosomal defects*, Fetal Diagn. Ther. 6 (1991) 46–57.

[2] F. Bernardino, R. Cardoso, N. Montenegro, J. Bernardes and J.M. de Sá, *Semiautomated ultrasonographic measurement of fetal nuchal translucency using a computer software tool*, Ultrasound Med. Biol. 24(1) (1998) 51-4. doi: 10.1016/s0301-5629(97)00235-4. PMID: 9483771.

[3] C. Bilardo, M.A. Müller, E. Pajkrt, S.A. Clur, M.M. van Zalen and E.K. Bijlsma, *Increased nuchal translucency thickness and normal karyotype: Time for parental reassurance*, Ultrasound Obstet. Gynecol. 30(1) (2007) 11-–18.

[4] R. Chaoui and K.H. Nicolaides, *Detecting open spina bifida at the 11- 13-week scan by assessing intracranial translucency and the posterior brain region: mid-sagittal or axial plane?*, Ultrasound Obstet. Gynecol. 38(6) (2011) 609-–612.

[5] V. Chalana and Y. Kim, *A methodology for evaluation of boundary detection algorithms on medical images*, IEEE Trans. Med. Imag. 16(5) (1997) 642-–652.

[6] Y. Deng, Y. Wang, P. Chen and J. Yu, *A hierarchical model for automatic nuchal translucency detection*, Comput. Biol. Medicine 42(6) (2012).

[7] Y. Deng, Y. Wang and P. Chen, *Estimating fetal nuchal translucency parameters from its ultrasound image, in: Proceedings of the International Conference on Bioinformatics and Biomedical Engineering*, IEEE (2008) 2643-–2646.

[8] L. Ding, P. Rangaraju and A. Poursaee, *Application of generalized regression neural network method for corrosion modeling of steel embedded in soil*, Soils Found. 59(2) (2019) 474–483.

[9] FMF. *Fetal Medicine Foundation nuchal translucency*, www.fetalmedicine.org.

[10] W. Lu, J. Tan and R. Floyd, *Automated fetal head detection and measurement in ultrasound images by iterative randomized Hough transform*, Ultrasound Med. Biol. 31(7) (2005) 929-–936.

[11] J. Moratalla, K. Pintoffl, R. Minekawa, R. Lachmann, D. Wright and K.H. Nicolaides, *Semi-automated system for measurement of nuchal translucency thickness* Ultrasound Obstet. Gynecol. 36(4) (2010) 412—416.

[12] K. Nicolaides, G. Azar, D. Byrne, C. Mansur, K. Marks, *Fetal nuchal translucency: Ultrasound screening for chromosomal defects in first trimester of pregnancy*, BMJ. 304 (1992) 867-–369.

[13] K. Nicolaides, *The 11-13 weeks scan*, Fetal Med Foundation, (2004) 71–88.

[14] K. Nicolaides, G. Azar, R.J. Snijders and C.M. Gosden, *Fetal nuchal oedema: associated malformations and chromosomal defects*, Fetal Diagn. Ther. 7 (1992) 123–131.

[15] K. Nicolaides, G. Azar, D. Byrne, C. Mansur and K. Marks, *Fetal nuchal translucency: ultrasound screening for chromosomal defects in first trimester of pregnancy*, BMJ. 304 (1992) 867–869.

[16] S. Nirmala and V. Palanisamy, *Measurement of nuchal translucency thickness for detection of chromosomal abnormalities using first trimester ultrasound fetal images*, Int. J. Comput. Sci. Inf. Secur. 6(3) (2009) 101-–106.

[17] S. Nirmala and V. Palanisamy, *Measurement of nuchal translucency thickness for detection of chromosomal abnormalities using first trimester ultrasound fetal images*, Int. J. Comput. Sci. Inf. Secur. 6(3) (2009) 101—106.

[18] P. Perona and J. Malik, *Scale-space and edge detection using anisotropic diffusion*, . IEEE Trans. Pattern Anal. Machine Intell. 12(7) (1990) 629–639.

[19] FA. Saldanha, L. Brizot Mde, EA. Moraes, LM. Lopes and M. Zugaib, *Increased fetal nuchal translucency thickness and normal karyotype: Prenatal and postnatal follow-up*, Rev. Assoc. Med. Bras. 55 (2009) 575-–580.

[20] G. Sciortino, D. Tegolo and C. Valenti, *Morphological analysis combined with a machine learning approach to detect ultrasound median sagittal sections for the nuchal translucency measurement*, Pattern Recognition: 9th Mexican Conf. (2017) 257-–267.

[21] D.F. Specht, *A general regression neural network*, IEEE Trans. Neural Networks 2(6)(1991) 568–576.

[22] J. Szabo and J. Gellén, *Nuchal fluid accumulation in trisomy-21 detected by vagino sonography in first trimester*, Lancet. 336 (1990) 1133.

[23] M. Vogel, G.K. Sharland, D.B. McElhinney, V. Zidere, J.M. Simpson, O.I. Miller and L.D. Allan *Prevalence of increased nuchal translucency in fetuses with congenital cardiac disease and a normal karyotype*, Cardiol Young. 19 (2009) 441—445.

[24] Y.-B. Lee, M.-J. Kim and M.-H. Kim *Robust border enhancement and detection for measurement of fetal nuchal translucency in ultrasound images*, Med. Biol. Eng. Comput. 45(11) (2007) 1143–1152.