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Artificial Intelligence in Cardiac Topographic Ultrasonographic Screening: The Journey to Gitam SHK Probe (Shishu Hridya Kavach)

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There is a universal consensus for the need for early detection of cardiac anomalies of the fetus amongst the obstetricians. Small complicated structure of a rapidly moving fetal heart posed insurmountable problems initially but persistence seems to pay off finally. The new hybrid technologies like the Bayesian Deep learning with Bayesian filter and deep learning intelligent neural network has been used for fetal ECG signal processing. Accuracies of over 90% is reported for ANN (Figure 1) and ELM for Cardiotocography [1,2]. Standard fetal ultrasound planes includes upper abdomen, 4 chamber view, 5 chamber view, short axis view, 3 vessel trachea and if needed longitudinal planes of aortic arch, the ductal arch and systemic veins.

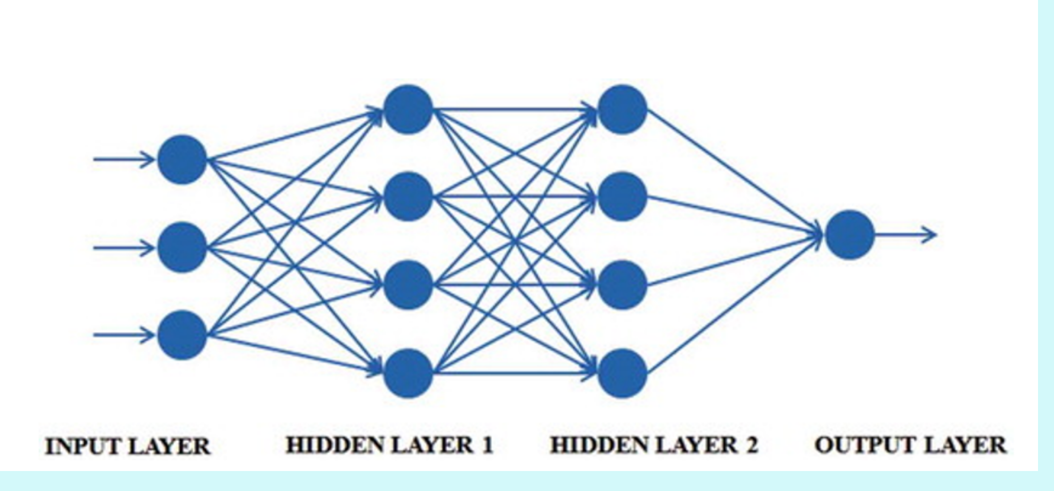

Figure 1: *ANN example.*

There are problems related to acoustic noise and necessity of high precision using conventional technology too [3,4]. Many groups internationally and so is a group of researchers headed by Prof Pradeep Kumar Radhakrishnan at Gitam University, in India are working on use of novel advanced intelligence algorithms for automatic detection of anomalies of fetal heart. This could overcome the observer bias and help in early diagnosis, planned and prompt treatment that could revolutionize neonatal medicine in future. 20% of newborn deaths are due to congenital heart anomalies. Rapid strides in deep machine learning applications can allow diagnostic devices to rapidly and accurate pick up abnormalities that facilitate easy diagnosis and prompt interventions [5-10]. A set if teacher data that the machine learns is prepared through annotation and train the object detection system. Positional abnormalities can be easily picked up. A certain subset of 13 - 18 different cardiac parts can be annotated to correct positions to develop a cardiac screening topographic algorithm. Beyond calculated confidence values between test data and learned data the abnormality is diagnosed and this can happen in real time eliminating observer errors [11-13]. This device can go to doorstep and can also harmonize diagnosis in different centers around the globe. A large number of ultrasonic images have to be incorporated to improve diagnostic accuracy. Cloud based platforms can be integrated into this for remote diagnosis.

Object detection technology developed from training data made of normal cardiac topography is done first. With insufficient or incomplete data robust learning techniques are used. Vertical axis represents the scanned part and horizontal axis represents the timeline. Skill gap amongst sinologists are thus eliminated by this method.

Recent developments in ultrasound imaging have been very promising in this direction too. Use of matrix probe for example allows examination of cardiac topography in two orthogonal planes simultaneously which helps in display of anatomy side by side in biplane mode. Live 4 D images with quick acquisition of STIC volume are possible.AI enables minimizing the operator dependency with automatic standardization of acquired images. Better image recognition software's would revolutionize this field. Matrix probes can reduce the noise too in acquisition [14,15].

Recently the Japanese group formed by Fujitsu, RIKEN, and Showa University developed the novel Fetal Cardiac Ultrasound Screening Technology that utilizes AI (Artificial Intelligence) to automatically detect heart defects in fetuses with high accuracy by comparing the detection state with the positions of the parts of a normal heart (Figure 2 and 3) [9].

	10 weeks	11 weeks	12 weeks	13 weeks	13 + 6 weeks
Four-chamber view	Yes	Yes	Yes	Yes	Yes
Outflow tracts	–	–	Yes	Yes	Yes
Aortic and ductal arches	–	–	Yes	Yes	Yes
Both cava veins	–	–	Yes	Yes	Yes
Pulmonary veins	–	–	–	Yes	Yes

Figure 2

Cardiac defects that should be detected	Transposition of the great arteries Double outlet right ventricle Hypoplastic left heart
Cardiac defects that might be detected	Coarctation of the aorta Tetralogy of Fallot AV canal or atrioventricular septal defects Truncus arteriosus
Cardiac defects unlikely to be detected	Ventricular septal defects Ebstein's anomaly Mild aortic and pulmonary stenosis Cardiac tumors Myocardial hypertrophy Fibroelastosis Abnormal pulmonary venous return

Figure 3: *Cardiac anomalies that can be detected at 11 weeks +/- 6 weeks.*

Age of visualization of various cardiac structures is given below.

Latest developments

Sishu Hridya Kavach- SHK Probe is being developed at Gitam University in India - for fetal cardiac screening with real time localization. The basic philosophy that works in similar object detection platforms is the basis of convolution neural network or faster R-CNN/ weakly supervised CNN or regression based object detectors such as SSD based on CNN or YOLO that is comparatively less accurate. For accuracy faster R CNN or when speed is needed SSD is chosen. Depending on the tradeoffs between accuracy and speed one has to converge upon combinations of recurrent and convolution neural network. Techniques to feed data- data cleaning or preprocessing has to be done like removing noises, rescaling, contrast adjustments threshold like Otsu to train the chosen model or may be directly fed.

Conclusion

3 D/4D technology with better image recognition software will enhance the ability of quick accurate and simple real time diagnosis for fetal cardiac screening that would help in the triage of high risk pregnancies [14-16]. SHK (Sishu Hridya Kavach) Probe being made with AI enabling is one similar software enabled probe that is currently in the work bench stage at Gitam University, Andhra Pradesh in India.

Bibliography

1. DAD Campos., *et al*. "FIGO consensus guidelines on Intrapartum fetal monitoring: Cardiotocography". *International Journal of Gynecology and Obstetrics* 131.1 (2015): 13-24.
2. P Fergus., *et al*. "Prediction of Intrapartum, Hypoxia from Cardiotocography Data Using Machine Learning". *In Applied Computing in Medicine and Health*, Waltham, Morgan Kaufmann, Elsevier (2016): 125-146.
3. M Lichman. UCI Machine Learning Repository, California: University of California, School of Information and Computer Science (2013).
4. S Ravindran., *et al*. "A Novel Clinical Decision Support System Using Improved Adaptive Genetic Algorithm for the Assessment of Fetal Well-Being". *Computational and Mathematical Methods in Medicine* (2015): 1-11.
5. Yeo L., *et al*. "Fetal intelligent navigation echocardiography fine detects 98% of congenital heart disease". *Journal of Ultrasound in Medicine* 37.11 (2018): 2577-2593.
6. DeVore GR., *et al*. "Two dimensional speckle tracking of fetal heart: a practical step-by-step approach for the fetal sinologist". *Journal of Ultrasound in Medicine* 35.8 (2016): 1765-1781.
7. DeVore GR., *et al*. "4D fetal echocardiography-An update". *Echocardiography* 34.12 (2017): 1788-1798.
8. Veronese P., *et al*. "A Prospective Study of the Use of Fetal Intelligent Navigation Echocardiography (FINE) to Obtain Standard Fetal Echocardiography Views". *Fetal Diagnosis and Therapy* 41.2 (2017): 89-99.
9. Fujitsu Blog. "Research of Fetal Cardiac Ultrasound Screening Using Al". *Journal of the American Medicine Association* 8 (2018): e186040.
10. Chaoui R., *et al*. "Three-dimensional (3D) and 4D color Doppler fetal echocardiography using spatio-temporal image correlation (STIC)". *Ultrasound in Obstetrics and Gynecology* 23.6 (2004): 535-545.
11. Chaoui R and Heling KS. "3D-ultrasound in prenatal diagnosis: a practical approach". 1st edition. Berlin (2016).
12. Espinoza J., *et al*. "Collaborative study on 4-dimensional echocardiography for the diagnosis of fetal heart defects: the COFEHD study". *Journal of Ultrasound in Medicine* 29.11 (2010): 1573-1580.
13. Hamill N., *et al*. "Fetal cardiac ventricular volume, cardiac output, and ejection fraction determined with 4-dimensional ultrasound using spatiotemporal image correlation and virtual organ computer-aided analysis". *American Journal of Obstetrics and Gynecology* 205.1 (2011): e1-10.
14. Abuhamad A and Chaoui R. "A practical guide to fetal echocardiography: normal and abnormal hearts". 3rd edition. Philadelphia (PA): Wolters Kluwer Health/Lippincott Williams and Wilkins (2015).

15. Xiong Y., *et al*. "A novel way of visualizing the ductal and aortic arches by real-time three-dimensional ultrasound with live xPlane imaging". *Ultrasound in Obstetrics and Gynecology* 39.3 (2012): 316-321.

16. MH Beale MT Hagan and HB Demuth, Neural Network Toolbox User's Guide, Natick: The Math Works, Inc (2015).