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White Paper

Computer-Aided Solution for Examination of Fetal Brain

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Introduction

Central nervous system (CNS) malformations are one of the most common congenital abnormalities. Ultrasound has been used for nearly 30 years as the major imaging modality to help diagnose fetal CNS anomalies [1]. Currently, the standard 2D planes used for ultrasound assessment of the central nervous system in fetuses include the Trans-Cerebellar Plane (TCP), the Trans-Thalamic Plane (TTP), and the Trans-Ventricular Plane (TVP). However, with the use of 3D, the acquisition of the Median or Mid-Sagittal Plane (MSP) adds a new and very clinically useful perspective.

The orientation of the Mid-Sagittal Plane provides a unique view of the intracranial structures such as the corpus callosum (CC) and an axial view of the cerebellar vermis (CV). Several studies[2~8] have proven that the observation from the MSP is critical for the clinical diagnosis of Agenesis of the Corpus Callosum(ACC) and Dandy-Walker Syndrome.

TCP, TTP, and TVP are the most critical planes in a fetal CNS examination. The anatomic landmarks in these planes include the cavum septi pellucidi (CSP), thalami, cerebellum, cisterna magna, and lateral ventricles. In addition to observing the morphology of these structures, measurements of this anatomy is also important to prenatal ultrasonography. The standard measurements of the fetal head include the head circumference (HC), biparietal diameter (BPD), and occipitofrontal diameter (OFD) from the TTP. The width of the cisterna magna (CM) and transcerebellar diameter (TCD) are obtained from the TCP and the width of the lateral ventricles (LVW) from the TVP.

Principle of Smart Planes

Machine Learning, a field of computer science, allows for the construction of computer algorithms that can learn from and make predictions on data. Learning-based detection is an innovative methodology in medical image analysis that applies the theories of machine learning and pattern recognition to detect interested anatomic structures. The basic idea of learning-based detection is to simulate the visual recognition process of a human by automatically selecting the appropriate features from the training dataset and further constructing the mathematical model to distinguish the attribution of input samples.

For Smart Planes, the training dataset consisted of over 5000 images of the general standard planes in fetal CNS (i.e., MSP, TCP, TVP, and TTP) that contain important anatomical structures (i.e., cerebellum, cavum septi pellucidi, corpus callosum, lateral ventricle and so on). The image features were first extracted using advanced image processing algorithms and then further applied to the training/learning algorithms to generate the final detection model. Based on the trained detection model, Smart Planes can automatically provide the likelihood of the input plane being one of the standard planes (MSP/TCP/TVP/TTP).

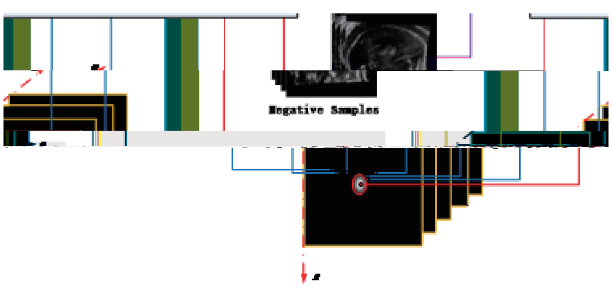

Fig.1 Workflow of standard plane detection.

Fig.1 shows the workflow of standard plane detection. The optimal standard plane is detected based on the features learned from positive and negative samples. In practice, MSP is first detected and the transverse planes (TCP, TTP, and TVP) are searched along the direction perpendicular to MSP. The search strategy is based on human anatomy which can both save the computational time and improve the robustness of detection.

In volumetric geometry, an image plane in 3D ultrasound data is given by:

$$\rho = \cos\theta \cos\varphi \quad + \sin\theta \cos\varphi \quad + \sin\varphi$$

The algorithmic goal of Smart Planes is to calculate the appropriate parameters [ ] that generates a target plane that fits the detection model best.

Benefit of Smart Planes

With the artificial intelligence based on 5000-case big data, Smart Planes provides a user-friendly tool that greatly improves scanning efficiency through increased accuracy coupled with automated operation. As illustrated in Fig.2, the traditional method usually involves a lot of manual adjustment which is user-dependent and time consuming, even for experienced doctors it could take minutes to find the standard planes; while with Smart Planes, with a simple button click on a 3D fetal brain volume image, the standard CNS scanning planes (MSP, TCP, TTP and TVP) and a range of related anatomical measurements (BPD, A fetus with both Dandy-Walker Syndrome and ACC is shown in Fig. 3. The size of the cerebellar vermis is smaller than normal and the shape of the cerebellum is different from normal (MSP, TCP in Fig.3A). What's more, the cavum septi pellucidi is very small and the length of corpus callosum is very short (MSP in Fig.3A). MRI confirmed these findings (Fig.3B).

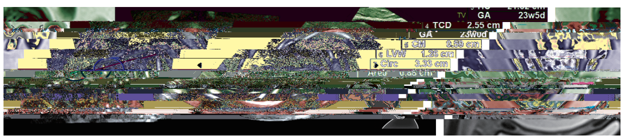

Fig.3 Dandy-Walker syndrome and ACC of case 1, the abnormal development in cerebellar vermis, cerebellum, cavum septi pellucidi, and corpus callosum are clearly displayed with accurate measurements.