EE 4331 Executive Summary

Detecting Abnormalities in the Volume of Amniotic Fluid in an Ultrasound by Applying Machine Learning Techniques

Background

Fetal health is at the forefront of pregnancies. Doctors have recurring appointments throughout the pregnancy to ensure the best health for mother and child. However, in some instances, babies suffer from issues created by inadequate levels of amniotic fluid which is the fluid that surrounds and cushions a baby in the womb. In the case of oligohydramnios in which amniotic fluid levels are too low, doctors focus on the cause of the issue, including family history and medication use. Physicians further use physical examinations to understand potential cause by testing for ruptured membranes, measuring fundal height, and performing a speculum examination. Current care only involves checking on the fetus and ensuring the maternal figure is hydrated adequately (Keilman 2022). As for polyhydramnios, where the amniotic fluid level is too high, common causes include gestational diabetes, fetal anomalies with swallowing, fetal infections, and additional, rarer causes. Polyhydramnios can be treated by amnioreduction pharmacological treatments. Amnioreduction involves inserting a needle into the amniotic sac to remove excess amniotic fluid (Hamza 2013).

The volume of amniotic fluid in the uterus is vital for the development of the fetus. Polyhydramnios increases the likelihood of problems including premature birth, cord prolapse – when the cord slips in front of the baby after the water breaks, or perinatal death. Oligohydramnios creates issues for fetuses such as incomplete development of the lungs. Creating a method to best understand whether a fetus is at risk for either polyhydramnios or oligohydramnios will ensure more accurate diagnostics for measuring fetal health and thus, increased positive fetal outcomes.

Current methods to determine the level of amniotic fluid include observations of ultrasound, where the technician estimates what they believe the level to be (Hamza 2013). Reliability of ultrasounds varies based on technician expertise, which can be dangerous for the health of mother and fetus. Obtaining the maximal vertical pocket (MVP), where the pocket of amniotic fluid with the greatest vertical length is identified, is another method to quantify the amount of amniotic fluid. The amniotic fluid index (AFI) is obtained by doing the same process as the MVP four times in which the uterus is divided into four quadrants and each quadrant's largest vertical pocket is identified and measured (Crellin 2023). The use of the AFI leads to the underdiagnosis of cases of oligohydramnios, while the MVP leads to the overdiagnosis of cases of polyhydramnios. Using segmentation on an image of a 3D ultrasound of the fetus would enable doctors to visualize and quantify the volume of amniotic fluid. This method enables any technician of any skill level to utilize the technology to get the same outcome and would be a noninvasive approach to accurately quantify the amniotic fluid to understand the state of the fetus.

Hypothesis

The research hypothesizes that implementing machine learning clustering methods to identify the location of amniotic fluid in a 3D ultrasound will ultimately reduce poor fetal outcomes.

Dataset

The dataset I will be using is from a project consisting of 172,293 ultrasound images collected from 12,356 exam from 2015-2021. Since the dataset consists of images, there are no specific

features. The data does include a .csv file with seven features that will not be used directly in the process of predicting the level of amniotic fluid (Burgos-Artizzu 2020).

Procedures

For the proposed research, I will employ two primary clustering techniques: k-means and hierarchical clustering. The first clustering technique to be used is k-means. Initially, we will preprocess the ultrasound images by converting them into a suitable color space such as grayscale and reshaping the image matrix into a 2D array, where each row represents the color values of a pixel. By applying the k-means algorithm, pixels will be grouped into k clusters, each corresponding to distinct regions within the image, like amniotic fluid or fetal tissue. Post clustering, each pixel will be assigned to its respective cluster, creating a segmented image where different regions are color-coded. To quantify the amniotic fluid, we will calculate the area covered by the amniotic fluid cluster, counting the number of pixels and converting it into a volume measurement based on the image resolution.

On the other hand, hierarchical clustering offers an alternative approach. Similarly, we will preprocess the images and reshape them into a 2D array. We will compute a linkage matrix using the Ward method, which aims to minimize the variance within each cluster. A dendrogram will be constructed to visualize the hierarchical structure of the clusters, helping us determine the optimal number of clusters. Once the clusters are formed, each pixel will be assigned to its respective cluster, creating a segmented image. Like k-means, the area covered by the amniotic fluid cluster will be calculated and converted into a volume measurement.

By leveraging these clustering methods, we aim to produce segmented ultrasound images that consistently and accurately quantify amniotic fluid levels, regardless of the technician's expertise. This approach ensures reliable diagnostics, ultimately improving fetal health outcomes.

Validation Process

To validate the process, the dataset will be divided into three parts—training set, validation set, and test set. This ensures the model is trained on one portion, tuned on another, and evaluated on a separate, unseen part of the data. Additionally, the segmented ultrasound images will be visually inspected to ensure that the amniotic fluid regions are correctly identified. This can be done by comparing the model’s output with expert annotations or existing diagnostic methods.

Anticipated Results

The proposed research will create an efficient way to quantify the volume of amniotic fluid in ultrasounds which will inform doctors of the direction of which care should be taken regarding the health of the fetus. This process will increase the outcome for fetuses whose amniotic fluid level is above or below the normal range. If the levels are in a normal range, then additional steps will not be necessary.

References

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