Automatic Image Registration and Stitching in 3D Ultrasound for Monitoring of Neonatal Post-Hemorrhagic Ventricle Dilation

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Introduction: Neonatal post-hemorrhagic ventricle dilation (PHVD) occurs in pre-term babies when the ventricles become obstructed and cerebrospinal fluid (CSF) cannot circulate once produced causing increases in intracranial pressure (ICP). Regular monitoring is necessary to determine the necessity of surgical intervention to treat ICP-related symptoms. Three-dimensional (3D) imaging modalities provide clinicians with important anatomic detail not available when a medical image is confined to 2D. 3D ultrasound (3DUS) is an advantageous imaging modality for neonates as no ionizing radiation is used, and the infant can remain in the incubator. For large ventricles, a single 3DUS image often cannot capture the entire ventricular system in a single scan. We hypothesize that if multiple overlapping images are obtained, a 3D panoramic view of a neonate’s brain can be automatically created with no user input to provide similar advantages to other 3D scanning modalities, allowing cost effective and accurate monitoring of the infants while still in the incubator.

Methods: Our lab previously developed both the technology to create 3DUS images using standard ultrasound equipment, a motorized housing, and a software application, which captures 2D ultrasound images and location information for the motor system to generate a 3DUS image, and this project builds on that work. We have established a registration pipeline including a Powell optimizer, Normalized Cross Correlation metric, and Rigid 3D transform along with a Nearest Neighbour interpolator. A rigid transform was applied as the brain is not expected to deform in the time between the scans. The images were cropped and masked to exclude extraneous or non-image data from the metric calculation. Additionally, the images were subsampled by a factor of 8 to reduce computation time. A large initial step-length in the
registration algorithm was set to ensure the overlap region was traversed in every dimension prior to step-length reduction. The resulting registered moving-image was blended pixel-by-pixel with the fixed-image by using a simple averaging filter with the fixed-image data.

Results: As shown in Figure 1 the preliminary images tested look qualitatively well aligned and stitched. The NCC value for this particular pair of images was measured at 0.60 after optimization. Additionally, subsampling reduced the registration time from 120 seconds to 22 seconds, with stitching taking 8 seconds in both cases. This result required no user input other than selecting images that overlap.

![Figure 1: Screenshot showing the two images to be registered and combined (a, b) and a stitched image (c) after registration](image)

Conclusions: Our method for registration and stitching will be validated upon further study. To this end we plan to validate the technique through using pairs of MRI and 3DUS scans obtained within 24 hours from the same patients. The measured ventricle volumes in 3DUS and corresponding MRI images will be compared using a linear regression, Bland-Altman analysis, and target registration error (TRE). Given previous work comparing 3DUS to MRI in other organs, we would expect some significant differences in the registered surfaces, specifically in the lateral most margins of the images, but this has yet to be proven in the neonatal head.