FLEXIBLE RECONSTRUCTION AND CORRECTION OF UNPREDICTABLE MOTION FROM STACKS OF 2D IMAGES

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SETTING

Problem: Motion makes it very difficult to examine 3D (fetal) MRI. Reconstruction and motion compensation are required.

Motivation: To provide an accurate and robust motion compensation method that is applicable to the whole scan, e.g., whole uterus and does not require manual definition of a rigid area.

Hypothesis: Splitting the input data into small overlapping patches, reconstructing from them and learning their consistency can provide a way to compensate motion in large, non-rigid areas and to reject uncorrectable areas by evaluating a learned consistency model.

Novelty: We evaluate square and evenly distributed patches for the reconstruction as well as patches that have been derived from super-pixels. Both approaches achieve on 20 subjects aged between 22–37 weeks a good reconstruction quality and provide a segmentation prior for rigid areas.

METHOD

Fig. 1: An overview over our approach. Bold parts are extensions to SVR.

Data acquisition:
- Fast MR sequences such as single shot fast spin echo (ssFSE) [1] are often used in order to freeze motion within a single 2D image.
- Usually six to twelve stacks need to be acquired to sufficiently oversample a 3D volume, which allows subsequent slice-volume reconstruction (SVR) [2].

3D motion compensation:
- Currently, the brain [2], thorax [3], and the appearance of the whole fetus [4] are qualitatively examined using MRI in the clinical practice.
- Organ segmentation and localization is required. Automatic approaches provide either a very rough segmentation of the central slices of a stack [5] or require less motion corrupted stacks [6]. Furthermore, they are only applicable to a specificity trained region, e.g., the fetal brain.

Evaluation: 29 fetal scans with gestational ages between 22–37 weeks.

Fig. 2: Comparison of the proposed reconstruction methods (right) to the state-of-the-art (left).

EM evaluation: Use only voxels that can be well registered and that have a minimal intensity error ε when compared to the originally scanned data! Classification via online trained expectation maximization (EM) framework with zero-mean Gaussian distribution $G_{\mu}(c)$ with variance $\sigma^2$ for the inliers and a uniform distribution with constant density $m = \max(c) - \min(c)$ for the outliers. We use overlapping patches to maximize the log-likelihood

$$y_i \cdot \log(P(Y_i, \Phi)) = \sum \log P(e_i | \sigma, c).$$

$\Phi$ current estimate of the reconstructed volume $X$, $\sigma^2$ the variance of the errors $e_i$, $c$ the proportion of correctly matched voxels. The posterior probability for a pixel being identified as inlier is $p = G_{\mu}(c) + m(1 - c)$. We perform the updates of $c$ and $\sigma^2$ similar to [2]. Using $\bar{p} = \left(\frac{1}{N} \sum_{i=1}^{N} \bar{p}_i\right)$ we can also define an inlier and outlier probability for each patch $\bar{y}_i$ and stop processing this patch if it gets classified as outlier.

Rigid segmentation priors: Keeping track of the probability $p$ of each pixel allows to identify areas that best fit the rigid 2D-3D registration constraint of potentially subsequently applied classical SVR reconstruction.

RESULTS

Fig. 3: Visual comparison between the input data (a) and different configurations for full fetal body reconstruction of a motion corrupted 3T MRI dataset (GA 33 weeks), (b) classical SVR, (c) square patches, (d) superpixels, (e) rigid area prior.

Fig. 4: PSNR in the white matter region of 29 subjects for different successful patch configurations compared to standard SVR (baseline).

REFERENCES


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