# Unsupervised Correction of Physiologically-induced Slice-offsets in 4D Cardiac MRI

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## Introduction

Spatio-temporal cardiac MRI investigations are typically acquired using a breath-hold technique where each short-axis slice is recorded over a set of time phases during one single breath-hold. Subsequent slices use new breath-holds with potentially different inspiration levels. This causes slices in the apex-basal direction to be misaligned. Fig. 1 (left) illustrates the problem.

## Purpose

This work presents a rapid and unsupervised method correcting for respiratory noise in dynamic three-dimensional cardiac MRI. Statistical models of shape and appearance are employed to localise the left and right ventricle in a mid-apex-basal, short-axis slice. The segmented region is subsequently propagated through all slices in the apex-basal direction using a non-rigid registration process, thus providing an estimate of the inter-slice translation due to variation in inspiration. Qualitatively and quantitatively validation carried out on 13 subjects appear very promising.

## Methods

The data material comprises 14 spatially corresponding, short-axis, end-diastolic, 2D slices (set A), and an independent set of 13 short-axis, dynamic volumes (set B), both acquired by a 1.0 Tesla Siemens Impact scanner with an ECG-triggered, FLASH sequence. Matrix=256x256, field of view=263x350 mm, slice thickness=10 mm (2D slices) and 6 mm (volumes), phase time=55 ms. Volume sizes were typically (*x/y/z/phases*) = 256x256x25x11 voxels.

Inter-slice variation in corresponding phases consists of two major components, i) the spatial physiological changes, and ii) the movement of the heart and upper abdomen due to respiration. To estimate the latter, the cardiac area is located using an active appearance model of the left and right ventricle (LV, RV) registered to the central 50% of all end-diastolic slices in each 4D cardiac MRI. The slice that provides the best model fit (in a least squares sense) denotes the *reference slice*, Fig. 1 (middle). From this slice a region of interest and a *reference point* are propagated through every frame in the basal direction and subsequently in the apex direction. Propagation is carried out in a four-dimensional space composed of translation, scaling and rotation by iteratively applying parameter updates based on a gradient matrix pre-computed from the previous slice. The initial reference point is the centre-of-gravity (COG) of the LV endocardial contour in the reference slice. The obtained reference points thus constitute estimates of the in-plane translation of the heart induced by inspiration. Finally, re-sampling all time phases of the 4D image by inverting the estimated translations carries out the correction.

## Results

All 13 dynamic volumes in set B have been corrected using the above method showing a good qualitatively result. A typical result is shown in Fig. 1 (right) during the end-systole. Quantitatively results are obtained by manually annotating each end-diastolic, endocardial contour, enabling comparison of COGs with and without correction. Since well-corrected volumes are assumed to have co-linear slice COGs, a performance measure is the mean distance, $m$, to the long-axis incident with the mean COG of all slices. The original scans had on average $m$ = 6.7±0.3 mm compared to the rectified scans with $m$ = 4.2±0.2 mm (mean, std.err.). Estimation and correction took less than 10 seconds per subject, on a standard PC.

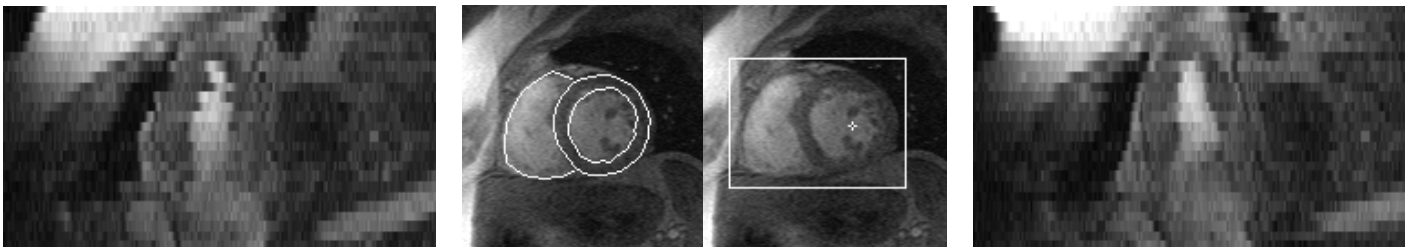

**Fig. 1.** *Left:* 4D input image, *Middle:* Reference slice with LV-RV localisation and region of interest. *Right:* Corrected 4D image.

## Conclusions

This work assume that respiration effects are purely in-plane translations and that the LV is rotational symmetric. Although we recognise that these are not entirely met, the approximations are adequate to produce results of significantly higher fidelity compared to the raw noise-corrupted scans. This improvement leads to better anatomical understanding, increase in annotation accuracy, and more specific cardiac shape models. The latter having applications to unsupervised dynamic analyses, ejection fraction estimation, et cetera.