Consistency in automated versus manual definition of MRI scan volume orientations of the human heart

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Introduction

Anatomically consistent and accurate definition of scan volume orientation for MRI scan planning is a prerequisite for diagnostic reliability. If the planning is done manually, it requires well-trained operators and a high level of concentration in order to produce consistent, reproducible results. Analoguously, automated approaches require robust, accurate methods for anatomy recognition as well as robustness in automated inference of scan volume orientations in presence of anatomical variability[1-2]. In this contribution, we present an automated scan planning approach for the human heart from MRI images that relies on a model-based segmentation approach[3-5] in combination with a learning-based planning algorithm[1]. With the variability of the automated system being comparable to the inter operator variability, and with its ability to reflect operator-specific preferences, the presented approach aims at a competitive solution for daily clinical routine satisfying strict constraints on computation time.

Methods

The proposed approach for consistent automatic MRI scan planning is composed of two modules, which are interfaced by a set of anatomical landmarks. Both modules will be described in detail in the following. The method is based on a dedicated, cardiac triggered, respiratory navigator compensated, 3D balanced TFE survey scan with 188×300×300mm field-of-view (1.5×2.5×2.5mm resolution) in sagittal acquisition direction, comprising the entire thorax in longitudinal as well as sagittal direction. Images were acquired on a Philips 1.5T Achieva scanner with a scan time of about 90 seconds.

Anatomy recognition: The proposed approach relies on the model-based segmentation[3-5], employing a triangulated surface model composed of the seven major parts of the heart[3-4]. After roughly positioning the model in the center of the image, segmentation is conducted in two steps: (1) pose optimization using global similarity transformations as well as localized affine transformations, and (2) energy minimizing free-form deformation using sequence-specifically trained, locally varying boundary descriptors[5]. Typical segmentation results, from which anatomical landmarks are calculated, are shown in Figure 1.

Scan geometry planning: Similar to earlier approaches[1-2], the proposed scan planning module is based on a set of training cases, assuming that for each training case scan volume orientations have been defined manually and anatomical landmarks have been extracted automatically. After registering the landmarks rigidly into a common reference frame, atlas landmarks are calculated as exact rigid registration of the cases is not feasible due to variability in anatomy and landmark extraction. Scan geometries of unseen images are obtained by again rigidly registering the atlas landmarks to their corresponding landmarks in the unseen image that have been extracted automatically, and by transforming the reference frame accordingly.

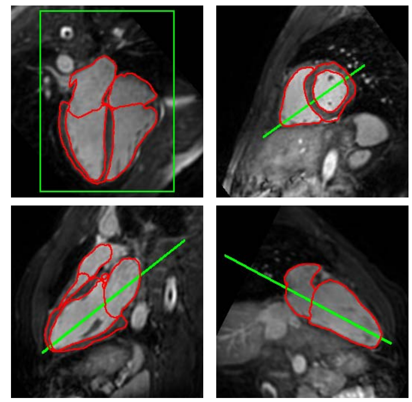

Figure 1: Example of anatomy recognition result on an automatically planned four chamber view (top left) together with three perpendicular cross-sections: short-axis view (top right), left and right two chamber views (bottom row).

Results

Performance of the approach was compared to operator variability in manual planning on the example of a four chamber view of the human heart. Five operators (A–E), all well-acquainted with the task of scan planning and with the anatomy, were asked to manually define anatomically consistent four chamber views on a set of 17 images from 12 healthy volunteers, 5 volunteers being scanned twice (see Figure 2 for an example). Operator variability is reported in the left section of Table 1 in the form of angular deviation of the defined plane in degrees as well as position deviation of the centre of the geometry in mm. The central section reports variability of automated results having been planned from a single manual plan of one operator with respect to all other manual plans of the same operator. The right section reports variability of automated results having been planned from all-but-one manual plans of a single operator with respect to manual plans of all operators on case left out.

Variability Operators A – E		Inter Operator			ASP–operator (1)			ASP–operator (2)		
		mean	SD	max	mean	SD	max	mean	SD	max
samples (per operator)		N = 68			N = 272			N = 85		
A	angular deviation	5.66	3.22	19.8	7.66	4.95	21.7	6.65	4.21	20.7
	center distance	9.20	4.93	25.3	6.26	3.31	17.0	9.10	5.14	22.8
B	angular deviation	4.39	2.98	13.6	8.52	4.58	19.3	5.91	3.09	15.8
	center distance	10.30	5.85	27.5	6.97	3.93	20.2	8.90	5.08	24.3
C	angular deviation	4.61	3.07	12.4	8.06	4.11	22.2	6.17	3.14	15.7
	center distance	14.40	7.98	31.3	6.35	2.40	12.6	12.70	8.16	34.5
D	angular deviation	4.97	3.64	19.8	9.17	5.09	23.6	6.12	3.10	15.0
	center distance	11.80	6.73	28.4	6.89	2.94	18.4	10.50	6.95	31.6
E	angular deviation	5.08	2.98	13.7	8.37	3.88	17.6	6.24	3.60	19.5
	center distance	16.90	7.58	31.3	9.50	5.54	27.6	15.80	7.57	29.2
		N = 340			N = 1360			N = 425		
all	angular deviation	4.94	3.20	19.8	8.36	4.56	23.6	6.22	3.45	20.7
	center distance	12.50	7.24	31.3	7.20	3.96	27.6	11.40	7.15	34.5

Table 1: Results of variability study. Deviation of one to all other operators (left). Deviation of automated method with learning from single plan of one operator to other plans of same operator (central). Deviation of automated method with leave-one-out learning from plans of one operator to plans of all operators (right).

Discussion / Conclusions

Figures in Table 1 reveal that the automatically generated scan geometries yield decreased variability in center positions compared to inter operator variability. Anatomical differences between subjects show effect on angular consistency, while leave-one-out experiment indicates increasing power of the planning method due to a broader training set by decreasing angular variability. A computation time of 20 seconds including planning is assumed to be competitive for clinical routine.

References

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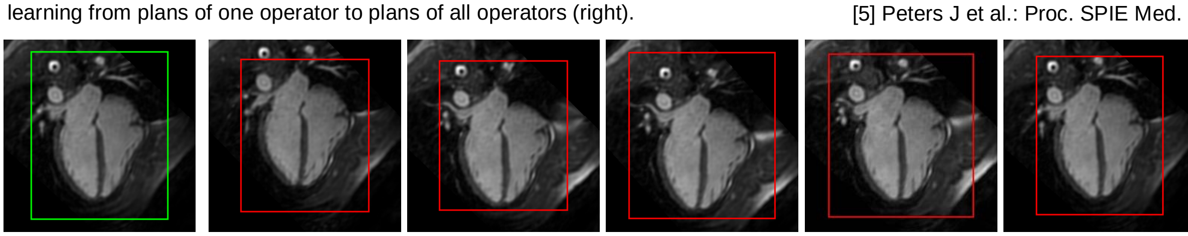

Figure 2: Example of an automatically generated four chamber view scan volume orientation (far left) in comparison to manual equivalents defined by each of the five operators.