Artificial intelligent technique for measuring heart volume from MRI images using iterative salient isolated threshold optimization ant algorithm (ISITOAA)

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Introduction: Ventricular volumes are usually measured from MRI images through manual delineation of the left and right ventricles (LV, RV) endocardial contours in a stack of parallel short-axis images. However, manual segmentation consumes long processing time and reduces measurement consistency. In this study, a new artificial intelligence technique (iterative salient isolated threshold optimization ant algorithm, ISITOAA) is developed and implemented for measuring ventricular volumes through automatic delineation of blood-myocardium boundaries.

Methods: Eight volunteers were scanned on a Siemens 3.0T MRI scanner to acquire cine short-axis images covering both ventricles. The ISITOAA technique was implemented on all images to delineate LV and RV endocardial contours, from which ventricular volumes were measured using Simpson's approximation, and compared to manual segmentation (gold standard). Fig.1 describes the ISITOAA algorithm (and parameter settings), which is composed of iterative implementation of two stages: adaptive segmentation (using salient thresholding) and boundary detection (using trapped ant algorithm (TAA)), as shown in Fig. 2. The ISITOAA technique is based on actual ant colonies by simulating the adaptive process by which ants find food and transfer it to their nest (foraging). Ants communicate by dispersing pheromone on the path they have traveled. When ants encounter pheromone, they move accordingly with stochastic rules. The assumption is that the trail of pheromone will converge to optimal solution. When ants from the same salient region cross another's path finding another's unique key, they are recognized to be in the same region. Furthermore, ants that share one or more boundary points are considered in the same region. The resulting set of boundary points is associated with the number of ants belonging to it, which provides a measure of solution stability. If an ant is found to be in a non-salient region, it immediately dies. Further if an ant encounters a pixel greater than the threshold in a specified number of movements, it dies. When an ant encounters a pixel greater than the threshold, it adds its location to the set of pixels it predicts to be the boundary. Ants continue to process until a specified time is reached, when they are removed from the image, and analysis is performed. Statistical t-test and Bland-Altman analysis were conducted to test the ventricular volume differences between ISITOAA and manual segmentation.

Results: Fig.3 shows segmentation results of different volunteers with various degrees of complexity. ISITOAA processing time was 6 minutes per dataset for both LV and RV on an Intel dual-core 1.73 MHz personal computer (versus 30 minutes by manual segmentation). The t-test showed non-significant ventricular volume differences by ISITOAA and manual segmentation ($p > 0.1$). Bland-Altman analysis showed no bias between volume measurements as all differences lied within the 2 standard-deviations (SD) agreement limit. Mean ± SD for LV and RV volume differences were 3.8 ± 10.1 ml and -2.1 ± 14.2 ml, respectively. The corresponding correlation coefficients (r) were 0.93 and 0.91, respectively.

Discussion: LV and RV volume measurements by ISITOAA are in good agreement with the gold standard. The integration of salient thresholding segmentation in ISITOAA resolves ambiguous regions and leads to accurate boundary detection. The ISITOAA technique is significantly faster (parallel processing by different intelligent agents (ants)) and more consistent than manual segmentations. The technique provides both LV and RV segmentations in a single processing, and provides a stability measure to gauge the solution integrity (δ). The technique detects endocardial borders in the case of severe trabeculations, which is a challenging task for automatic segmentation, as shown in Fig. 3.

References: [1] Pauwels and Frederix. *Computer Vision and Image Understanding* 1999; 75:73-85.
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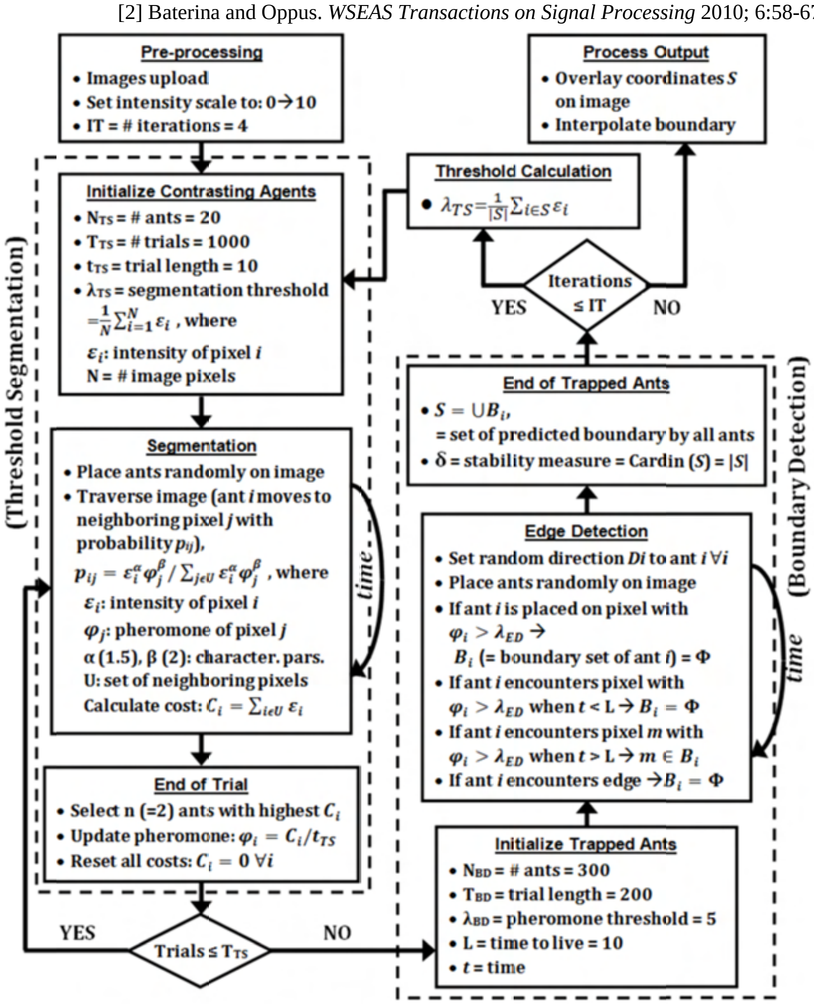

Fig 1. ISITOAA algorithm. It depends on iterative implementation of two steps: threshold segmentation (TS) and boundary detection (BD). Algorithm is based on ant colony optimization in combination with salient isolated thresholding.

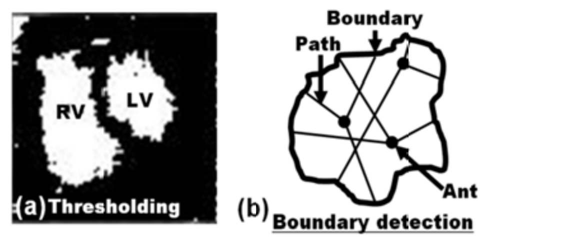

Fig 2. ISITOAA steps. (a) Salient thresholding. (b) Boundary detection: ants seek boundary through different paths.

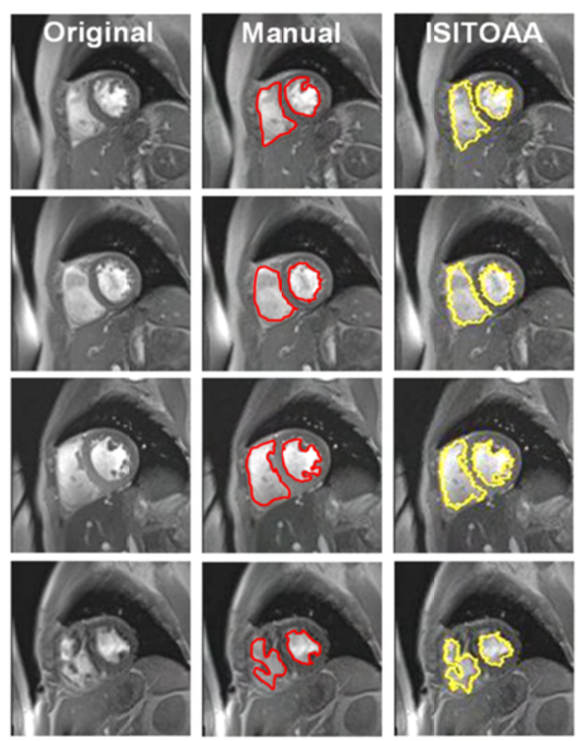

Fig 3. ISITOAA results vs. manual segmentation