Artery-Vein Separation For Vessel Analysis

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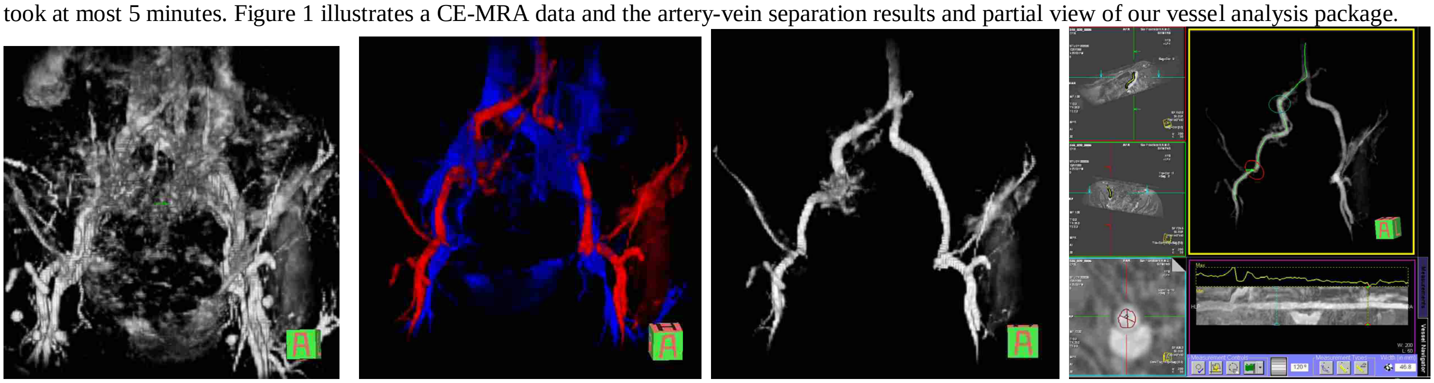
Introduction
Both arteries and veins are significantly enhanced in the MRA data when the MS-325 contrast agent [1] is used. However, arteries often need to be segmented and separated from venous structures for better visualization and quantification. A new algorithm which combines region based deformable models with the vessel centerline models is presented for the separation of arteries from veins in CE-MRA.

Method
We have developed a semi-automatic segmentation and separation algorithm in which the user selects few points on the arteries and veins by using VRT or MIP visualizations. In our algorithm, we *first* apply non-linear smoothing (filtering) to CE-MRA data. This algorithm considers the MRA data as a 4D surface and smooths it by evolving it based on its curvature information. Specifically, we use a Mean-Gaussian curvature [2], which removes noise but keeps vessel-like structures unchanged. *Second*, each seed point initiates a deformable model whose growth is modulated by the local and global statistics. When deformable models from vessels and arteries collide during the propagation they compete with each other for classifying regions with their own label until convergence. This region competition algorithm [3] separates arteries from vessels but it often produces errors. Specifically, deformable models representing veins (or arteries) can sometimes cross over the arteries (or veins) when the gap between them is small and then grow significantly until they collide with an artery (or vein) deformable model. This happens because we do not require very complicated seed placements. These errors could be avoided if the large number of seeds for both arteries and veins are symmetrically placed from each other. Instead of an advanced seed placement technique, we incorporated the centerline models of vessels. Specifically, we detect the centerlines between seed points from the segmentation and separation results. The centerline between seeds is constructed by using the Dijkstra's algorithm where the cost function is derived from the distance transform of the segmented vessels and the distance between seed points [4]. *Then,* deformable models are initialized from the centerlines for better separation of arteries and veins. These models again grow based on the local and global statistics and compete with each other when they collide. The incorporation of centerline models clearly improves the accuracy significantly. If errors occur, the user can add or delete more seeds to correct the results until he/she is satisfied with them. Since the computations are local in this algorithm, the computational burden of this correction stage is low. In addition, for further computational efficiency, we have developed a local smoothing technique where the smoothing is applied only at places where the deformable models visit.

Results and Discussions
We have developed an artery-vein separation algorithm for CE-MRA. The algorithm is user friendly since the user is only required to click on 3D visualization for placing seeds. The current implementation takes around 2 minutes on a Pentium 3 (1.5GHz) machine. We have successfully tested our algorithm on more than 20 abdominal CE-MRA data sets provided by EPIX Medical. In most cases, our algorithm performed successfully. When errors occurred in the results, the user corrected the results by adding more seeds without restarting the whole process. The correction process took at most 5 minutes. Figure 1 illustrates a CE-MRA data and the artery-vein separation results and partial view of our vessel analysis package.



(a) (b) (c) (d)

Figure1: (a) Original CE-MRA data; (b) results from the separation algorithm; (c) arteries after venous suppressions; (d) a snapshot of our vessel analysis package, which illustrates the three MPRs (left), VRT showing arteries after venous suppression and vessel centerline via green curve (right top), and the flattened visualization of the artery specified in the VRT by the green centerline curve (bottom-right).

References

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