Detection of Abdominal Aortic Aneurysm in MRI Images

18-980 Masters Thesis Project

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Outline

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1. The Problem
   - What is an AAA?
   - Motivation
   - The Aim
2. The Algorithm
   - Desirable Qualities of the Algorithm
   - Available Techniques
   - Mathematical Details
3. Results
   - The Working Program
   - Results on a Dataset
   - Limitations and Future Work

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Abdominal Aortic Aneurysm

- Localized dilatation of abdominal aorta, exceeding the nominal diameter (2 cm) by more than 50%.
- Caused by degenerative process of the aortic wall, however exact etiology remains unknown.
- Most important complication of AAA is rupture, spilling large amount of blood into abdominal cavity, causing fatality within minutes.

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Abdominal Aortic Aneurysm

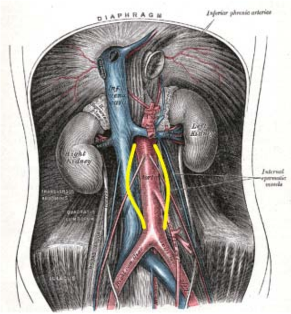

Figure: A plate from Gray's Anatomy [3] with yellow lines depicting the most common infrarenal location of the AAA.

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Need for Automatization

- An aneurysm is hard to detect because it is usually asymptomatic.
- Only symptomatic or large aneurysms (diameter $>$ 5.5 cm) are considered for repair.
- However, smaller aneurysms need to be kept under surveillance until they warran repair.
- MRI or CT images need to be analyzed for all patients with even the slightest risk, leading to a large dataset.
- Since the location of the AAA is uncertain, volumetric data needs to be analyzed.

The Aim

- Use segmentation techniques to seperate the lumen and the inner and outer walls.
- Estimate the change in diameter of the aorta, to detect the presence of an aneurysm.
- Measure the thickness of the wall, which is an indication of the stress on the aneurysm, and consequently the risk of rupture.

Challenges Faced

- The modality in question, fast spin echo MR imaging has a low resolution, 512×512 for a section of the entire abdomen.
- The amount of noise in the image is significant.
- Even though the imaging is fast, artefacts are introduced in the image due to involuntary patient movement, like breathing.
- These factors lead to failure of most of the normal segmentation techniques.

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Qualities Desired in the Algorithm

- Invulnerability to presence of involuntary motion artefacts.
- High resistance to noise
- Insensitive to low resolution.

Segmentation Techniques

Out of many segmentation techniques, the ones that might have the above qualities are:

- **Region Growing Methods:** Susceptible to motion artefacts.
- **Watershed Methods:** Region might not be simply connected.
- **Model-based Segmentation:** Promising, however, requires a robust model.
- **Levelset Methods:** Several factors can be included in the process, which when fine-tuned should give a very good segmentation result.

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The Chosen Approach

Thus the approach chnosen was thus levelset method.

- Can be used to efficiently address the problem of curve propagation in an implicit manner.
- The central idea is represent the evolving contour using a signed function, where its zero level corresponds to the actual contour.
- Implicit, parameter-free, provides a direct way to estimate the geometric properties of the evolving structure, can change the topology, intrinsic.
- Very efficient.

Factors Used

The levelset contour evolution can depend on several factors. The ones that are pertinent to the problem at hand were chosen:

- Contour evolution should be in normal direction.
- Since aorta has very smooth (almost circular) walls, contour curvature should be minimized.
- The contour evolution should slow down at edges, sharper the edge, slower the evolution
- The area enclosed is reasonably well defined.

Mathematical Details

- Initialization is a circle, smaller than the lumen.
- After the lumen is detected, the contour should be dilated by a small amount to find the next wall.
- The contour should grow, spurred on by the absense of edges and in search of minimum curvature.
- The levelset function should not change when the specified area has been reached.

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Mathematical Details

- The speed is inverse of the edge strength, with perturbation.

$$v = \frac{1}{1 + |\nabla I|^2}.$$

- The curvature of the contour is given by the curl of the normal to the levelset function ϕ.

$$\kappa = \nabla \cdot \left(\frac{\nabla \phi}{|\nabla \phi|} \right).$$

- The area factor is calculated as the difference between the target area and the current area.

$$v(A) = H\left(A_{max} - \int H(\phi)\, dA \right)$$

Mathematical Details

- The final evolution equation is a combination of the above factors with certain weights.

$$\frac{d\phi}{dt} = v \cdot v(A) \left(\mu\kappa \cdot \frac{\nabla\phi}{|\nabla\phi|} - \nu \cdot \frac{\nabla\phi}{|\nabla\phi|} \right).$$

Program Details

- All the differentials are realized by finite central differences.
- The time evolution is done iteratively using a finite time step.
- The levelset function is recalculated every 10 iterations.
- The user selects a region of interest smaller than the entire image, and the location and size of the initial circular contour.
- An external script applies the function to all the images in the current folder, with an option of carrying forward the ROI, initializations and area biases, and saves the images along with the segmentation data.

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The Working Program

Results on a Dataset

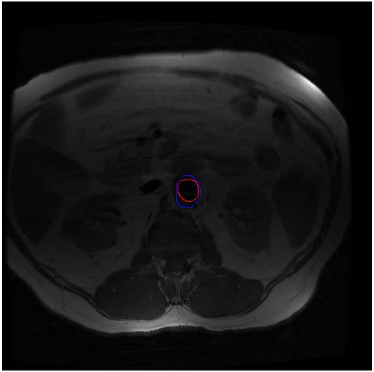

Figure: Dataset Slice 9

Results on a Dataset

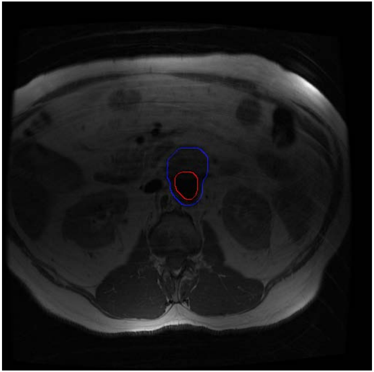

Figure: Dataset Slice 10

Results on a Dataset

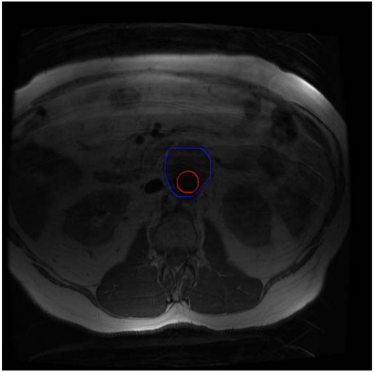

Figure: Dataset Slice 11

Results on a Dataset

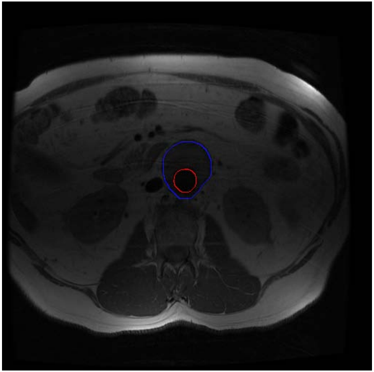

Figure: Dataset Slice 12

Results on a Dataset

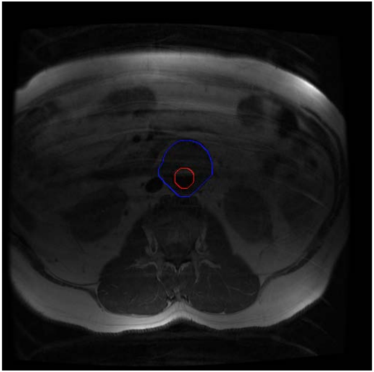

Figure: Dataset Slice 13

Results on a Dataset

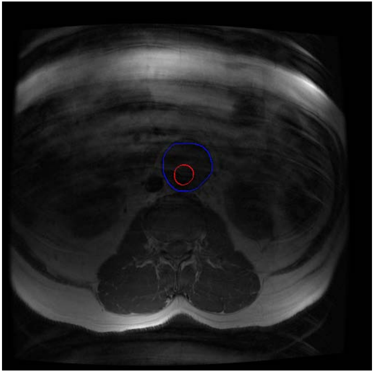

Figure: Dataset Slice 14

Results on a Dataset

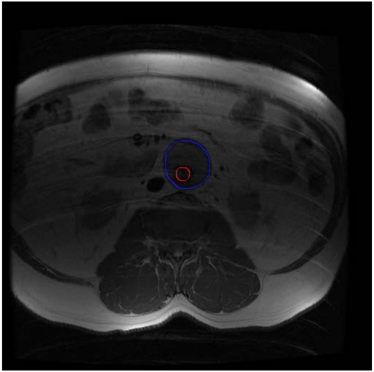

Figure: Dataset Slice 15

Results on a Dataset

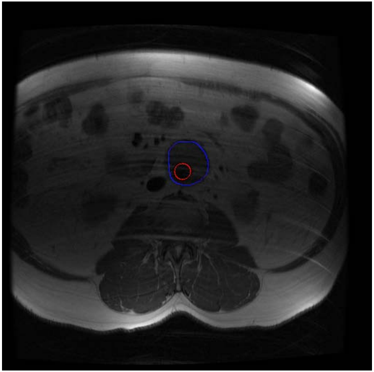

Figure: Dataset Slice 16

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Results on a Dataset

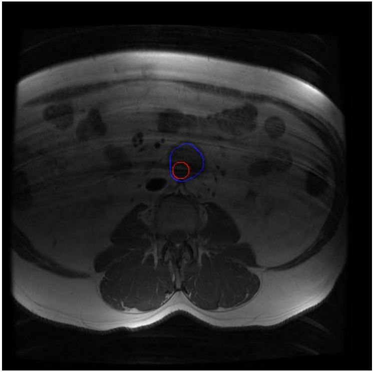

Figure: Dataset Slice 17

Limitations

- Needs atleast one initialization per set - can be overcome by using a large enough region of interest and nominal location and size of aorta.
- Cannot detect outer wall as yet, due to the small thickness - will probably need a reverse evolution (dilating the inner wall estimate by a large amount and working inwards)
- Takes a moderate computation time.

Future Work

- Segment the outer wall
- Estimate the diameters and wall thickness using the computed area, and generate diagnosis.
- Program a graphical user interface for the script.

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