A Smart Contour Editing Tool

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Abstract: Fibrosis in the myocardium (heart muscle) caused by ischemia of coronary arteries leads to ischemic cardiomyopathy. Cardiologists use contrast enhanced CMRI - Cardiac Magnetic Resonance Images to detect fibrosis. To accurately detect fibrosis, it is required to work upon a set of images which consumes a lot of time and reducing this time would be a significant improvement.

Deep learning models based contours are not completely accurate. To correct the error in contour, a tool called Nudge tool can be used. This tool helps in adjusting the contour points to correctly highlight the region of interest. However, there are a few issues in this tool. Firstly, it changes the shape of contour to concave while performing erosion, which is practically not possible to have. Secondly, it requires very fine control over the pointing device.

This work proposes an improvement over the Nudge tool. This tool lets you make delta (small) changes at a time without requiring fine control over the pointing device. Also it lets you snap the contour to the nearest region of high contrast.

Keywords : Fibrosis, Myocardium, Contour, Region of Interest, Nudge Tool

I. INTRODUCTION

Cardiologists use CMRI - Cardiac Magnetic Resonance Image to detect fibrosis (dead tissues in myocardium). To accurately detect fibrosis, it is required to work upon a set of images which consumes a lot of time. It would be easier for radiologists if this work can be done in less time (Even 50% reduction in time is very significant). To solve this issue, deep learning based models are used which segment the walls of the heart - epicardium, endocardium and myocardium. It then highlights the region as bright patches which are the dead tissues using contour.

However, this process does not always generate an absolutely accurate contour. The model used has a DICE value of 0.8 for the CMR images of heart, which is the current industry standard. To correct the error in contour, a tool called Nudge tool can be used. This tool helps in adjusting the contour points to correctly highlight the region of interest. However, there are a few issues in this tool.

Firstly, this tool can cause distortion in the shape of contours. When adjusting the contour from outside of the region (erosion), it changes the shape of contour to concave, which is practically not possible to have.
Secondly, it requires very fine control over the pointing device. These issues can lead to critical errors. To solve these errors, a tool named Delta Nudge tool is being proposed. This tool lets you make delta (small) changes at a time without requiring fine control over the pointing device. Also, snapping of contours is possible using this new tool. In case the contour is away from the region of interest in an arc, then it can be adjusted using two points as user input. Once the input is passed, the contour points automatically get snapped to the nearest region of high contrast (edge). Thus, it solves the issues associated with the Nudge tool and adds new functionality to it.

[1]. Images are nothing but a grid of pixels. Thus, image editing systems are basically pixel-based editing.This work proposes a novel method for image editing in which the main area of focus is not pixel but an edge.
Recent work showing a grey-scale image can be accurately represented by its edge map, suggests the feasibility of this proposal. In particular, an efficient algorithm has been reported in this work to invert such an edge representation to yield a high-fidelity reconstruction of the original image. The proposed method combines these algorithms together with an efficient method for contour grouping and presents an intuitive user interface which allows users to perform image editing operations directly in the domain of contour.

This method may lead to major improvements in the efficiency of certain classes of image editing operations, as suggested by experimental results.

[2]. It has been proven at multiple instances that image segmentation is the most challenging task in the domain of image processing. Even the best predictive models and automatic segmentation approaches cannot yet provide an accurate segmentation in every circumstance. Hence, there is a genuine need for an editing tool that corrects the automatic segmentation results such that they match the exact region of interest. This would prove to be a clinical revolution.

This work presents an editing approach that uses a user-drawn splice (contour) in 2D to correct any 2D or 3D segmentation that may have been generated incorrectly by any model. The algorithm is an integration of the image data, existing segmentation and user's input into the framework.
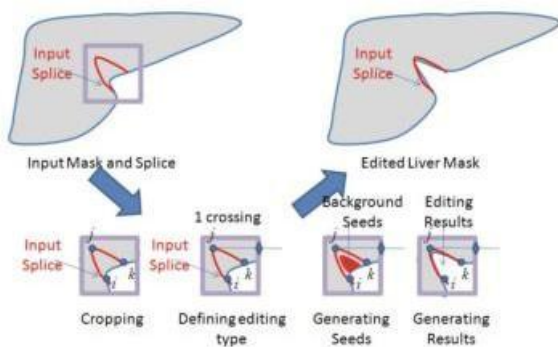
[3]. Recent developments in medical imaging techniques have given rise to an entirely new field of research in image processing. The main goal of this work is to improve medical diagnosis through segmented images. Techniques have been developed to help identify specific structures within a magnetic resonance image MRI. The Active Contour methods, these methods are adaptable to the desired features in the image. This work describes two classes of active contour models and discusses application aspects in the field of medical imaging. The main conclusion from this work is that there is no ideal segmentation method. Both parametric

and geometric active contours are driven by forces extracted from the image itself, which makes them extremely dependent on image quality, i.e., low noise, proper definition of the edges of the structures, and the absence of local minima. Finally, it is important to note that an efficient, accurate medical image segmentation system should necessarily add some intrinsic knowledge about the problem to the model.
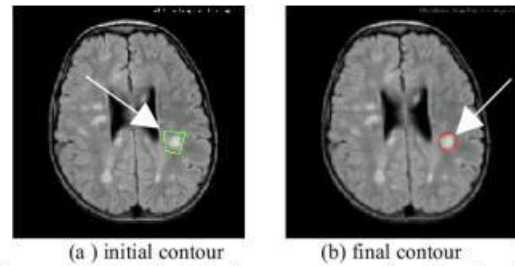

(a) initial contour   (b) final contour
**Figure 2** Pathological image segmented with classical

[4]. A common problem of most active contouring methods is that the recursive search scheme can only provide a local optimal solution. Moreover, the internal energy of the snake is not strong enough to control the shape of the contour. To overcome these difficulties, this work develops a causal internal energy notion based on a radial contour representation to encode the smooth constraint of the contour and develop a global shape prior to control the shape and position of the contour based on the object dynamics. The causal nature of the representation allows us to efficiently find global optimal solutions using dynamic programming. To verify the effectiveness and robustness of the proposed approach, they applied this approach to track individuals in poorly lit and cluttered environments.

This work reports promising results in the paper.

(Frame 344)   (Frame 355)

(Frame 357)   (Frame 370)

[5]. The segmentation of left ventricle in cardiac-magnetic resonance imaging is a necessary for the analysis and diagnosis of cardiac functionalities. In most cases, this steps are still manually performed

by cardiologists, which is time-consuming. This research-paper proposes a fast system for the segmentation of the left ventricle that reduces human intervention. A dynamic programming approach is used to obtain the border of the left ventricle. Using very simple approaches about the expected shape and location of the segmentation, this system is able to deal with many challenges associated with their stated problem. The system was evaluated on two public datasets: (i) with 33 patients, comprising a total of 660 magnetic resonance volumes and (ii) with 45 patients, comprising a total of 90 volumes. Quantitative evaluation of the segmentation accuracy and computational complexity was performed.

The proposed system is able to segment a whole volume in 1.5 seconds and achieves an average Dice similarity co-efficient of 86.0% and an average perpendicular-distance of 2.4 mm, which compares favourably with other state-of-the-art methods. A system for the segmentation of the left ventricle in cardiac magnetic resonance imaging is proposed. It is a fast framework that significantly reduces the amount of time and work required of cardiologists.
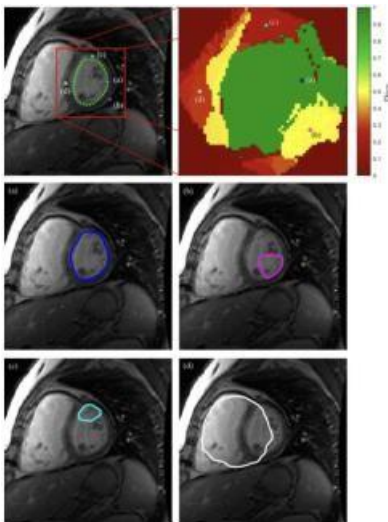

II. FIBROSIS

Fibrosis in the myocardium (heart muscle) caused by ischemia of coronary arteries leads to ischemic cardiomyopathy. Increased accumulation of extracellular matrix (ECM) that impacts cardiac function, is the underlying cause of fibrotic heart disease. There are four different types of cardiac fibrosis, including, reactive interstitial fibrosis, replacement fibrosis, infiltrative interstitial fibrosis and endo-myocardial fibrosis.

Fibrosis is detected manually by cardiologists using CMRI – Cardiac Magnetic Resonance Images.
However, using generic MRI, it is difficult to detect fibrosis. In order to better highlight the region of interest

(fibrosis), gadolinium is injected into a vein to improve the visualization of the region. Such an MRI is known as contrast enhanced MRI.

This manual process is time consuming. The cardiologists have to manually go through a number of MRIs in order to correctly detect the region of fibrosis. In order to eliminate the need to detect it manually, predictive algorithms can be employed. Using deep learning models, the region of dead tissues can be automatically highlighted using contours. Contours can be automatically created around the contrast enhanced region. However, deep learning models cannot be perfectly accurate. There is always a scope on improvement in the accuracy of the models. Detection of fibrosis is a very critical decision to make. Even the slightest bit of error can prove to be fatal. Thus there is a need to edit the automatically generated contour to correctly represent the actual region of interest.
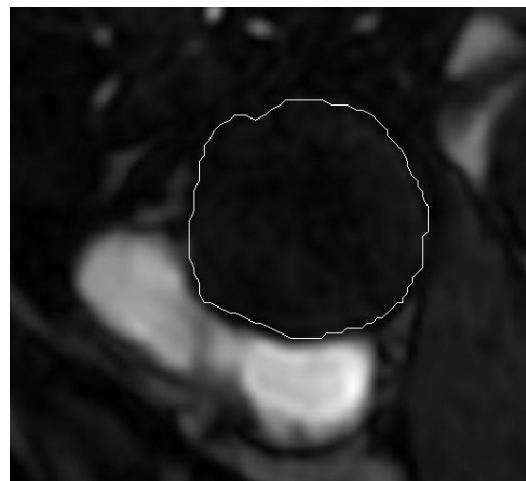
The image above shows the region of interest being represented using automatically generated contour, However, towards the bottom left of the image, the contour is not accurately highlighting the region. It can so happen that there is a need to edit it.
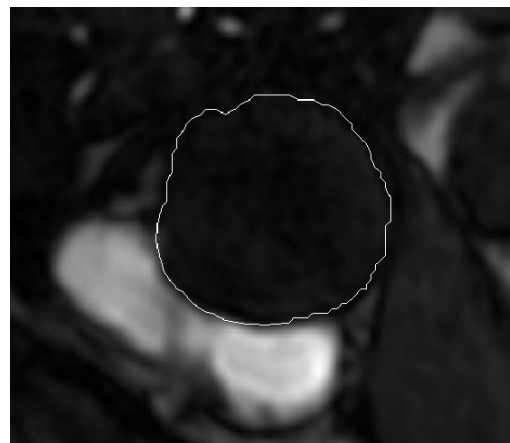
In the above image it is clearly visible that the contour has been edited towards the lower left region to bring it closer to the highlighted area.

III. RELATED WORK

Deep learning models used to automatically detect fibrosis and generate contour to highlight the region of interest, have accuracy issue. Owing to the fact that predictive algorithms cannot be 100% accurate, there is a need of a way to edit these contours to bring it as close as possible to the region of interest.

[6]. Automatic segmentation of anatomical structures is critical for many medical applications. However, the results are not always clinically acceptable and require tedious manual revision.
This paper presents a novel concept called Artificial Intelligence–Assisted Contour Revision (AIACR) and demonstrate its feasibility.

As part of our ongoing efforts to develop Artificial Intelligence and Clinician Integrated Systems (AICIS), this work aims to alleviate this practical problem of manual editing and to facilitate the clinical implementation of auto-segmentation models by using AI as an assistant to clinicians. In this work, a novel concept, is being proposed, of using AI to
assist clinicians in revising contours, which has been termed as Artificial Intelligence–Assisted Contour Revision (AIACR).

The following is the intended workflow for AIACR: given an input medical image, an initial contour is generated via an auto-segmentation model (or generated by a trainee); this initial contour is then reviewed, and revised when needed, by the clinician. During the revision process, the clinician indicates where the current contour should be with a simple mouse click at the desired contour boundary. The AI model updates the contour based on this input from the clinician, and the process repeats until an acceptable contour is achieved.
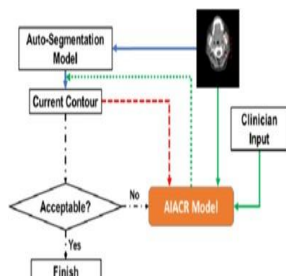
If the initially generated contour is to be revised, the clinician provides one mouse click on the desired boundary in the area with a large error, i.e. where the correct contour should be. This mouse click–based feedback guides the AIACR model to update the contour.

Specifically, the mouse click is converted into a 2D image (known as "click image") by placing a 2D Gaussian point with a radius of 10 pixels around the above boundary point. The inputs to the model – original image, current segmentation mask and click image. The output image is the updated contour.

The clinician then reviews the updated contour.
If it is acceptable, then the revision process is finished. If further revision is required, then the clinician makes a second mouse click in the area currently exhibiting the next largest error (again, where the contour should be). In this case, both the first and the second mouse clicks are converted into a single joint 2D click image by placing two 2D Gaussian points (each with a radius of 10 pixels) around the above two clicked boundary points.

The above process is repeated until the resultant contour meets the clinician's expectations.

TRAINING DETAILS:

C_p : Currently predicted contour
C_g : Ground truth contour
D_{C_p} : distance for every point on the ground truth contour to the nearest point on the predicted contour

$$D_{C_p}(y) = \inf_{x \in C_p} d(x, y) \; \forall y \in C_g$$

Assuming that the clinicians will likely click on the boundary points that correspond to the large errors, this distance is converted to click probability to use during the training phase using Softmax function. Based on this the contour is generated.

$$P(y) = \frac{exp\left(-D_{C_p}(y)\right)}{\sum_{y' \in C_g} exp\left(-D_{C_p}(y')\right)} \; \forall y \in C_g$$

RESULT:
To quantify the performance of AIACR model two metrics are used:
1. Dice coefficient (DSC)
2. 95th Hausdorff Distance (HD)

|	Initial	Click 1	Click 2
DSC	0.873	0.918	0.969
HD95(mm)	5.85	4.68	1.17
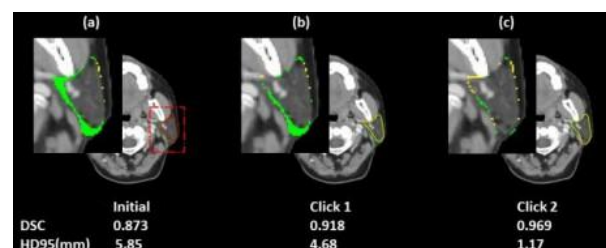
Above figure showcases for the segmentation of a left parotid gland from the validation dataset with 2 clicks. (a)-(c) show the segmentation results for the following time points: initial (a), after 1 click (b), and after 2 clicks

(c) with AIACR. Associated segmentation errors are demonstrated in the top left corner of each cell (green: false negative, yellow: false positive). Note how the area occupied by the segmentation errors decreases with each successive click, thus demonstrating the effectiveness of AIACR with user input.
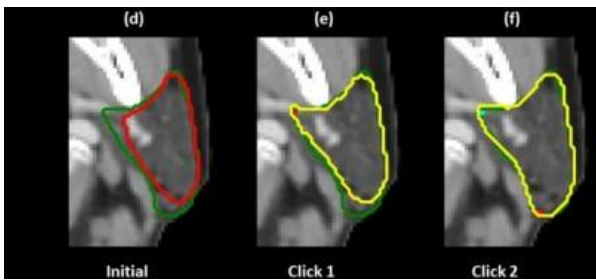
(d)-(f) show the zoomed-in contour comparisons of the left parotid glands (green: ground truth contour, red: initial contour, yellow: updated contour at each iteration) along with the clicked points (red: current clicks, cyan: past clicks).
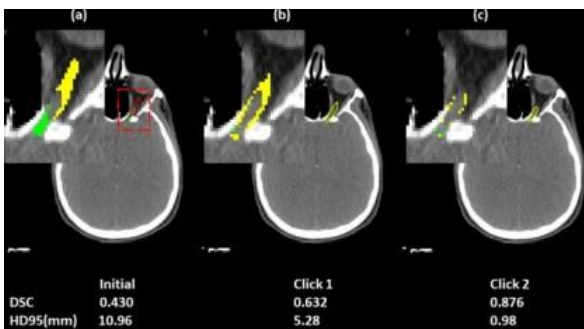
The above figure showcases for the segmentation of a left optic nerve from the DeepMind test dataset with 2 clicks. (a)-(c) show the segmentation results for the following time points: init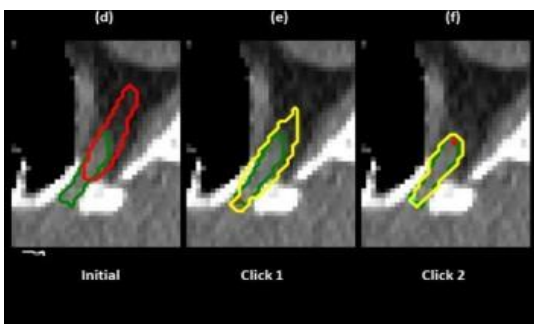ial (a), after 1 click (b), and after 2 clicks (c) with AIACR. Associated segmentation errors are demonstrated in the top left corner of each cell (green: false negative, yellow: false positive). Note how the area occupied by the segmentation errors decreases with each successive click, thus demonstrating the effectiveness of AIACR with user input.

(d)-(f) show the zoomed-in contour comparisons (green: ground truth contour, red: initial contour, yellow:

updated contour at each iteration) along with the clicked points (red: current clicks, cyan: past clicks).

IV. LIMITAIONS

There are various tools and techniques available which can be employed for the purpose of editing contours. There are basically two categories of tools that are available. One, deep learning based tools to edit contour as per user's input and direction while second is manual editing tools.

- Predictive contour editing tool use, in addition to using algorithm for prediction of contour, deep learning model to edit the contour based on various factors. The most prominent trigger for editing is user's input. User may provide the input in the form of a mouse click. This mouse click can represent the actual position of contour at a certain point. This process can be used iteratively to edit the contour to represent the actual region of interest. However there is a major limitation associated with it. The algorithm used to predict the updated position of contour might not produce 100% accurate results. Deep learning based model cannot be perfectly accurate as it is not achievable. Thus in the end there will a need for a tool to edit the contour manually.

- The second method is making use of manual editing tools. These tools let you edit the contour manually using a pointing device, generally mouse. Instead of predicting the updated position of contour after each user input, these tools let you edit the contour manually. The main advantage of this method is that the editing of contour can be done with the highest level of accuracy which is much needed in medical terms.

Nudge tool is a tool which is used for the purpose of editing contours. It lets you perform the editing manually. It is based on the Cornerstone.js library. In cases where the predicted contour fails to accurately represent the region of fibrosis, Nudge tool can be used to edit it. Though it serves the purpose, there are a few issues associated with this tool.

- In order to edit contours using Nudge tool, there is need to finely control to pointing device, mouse in most cases. This fine grained control is not feasible in cases where only a minute editing is required.

- In case of editing the contour from outside of the contour region, known as erosion operation, the shape of the contour gets distorted. This is mainly due to the fine grained control which is difficult to achieve. Due to this, the shape become concave which is practically not possible.

The above image is an MRI of parrot used as a reference To demonstrate the limitation of Nudge tool. Let's assume that the contour is not accurate towards the right portion. The contour should have been more compact to correctly align with the edge. However it is away from the edge. Thus it is required to edit the contour.

In an attempt to push contour from outside to align it with the edge, the shape of the contour has become concave. This is practically not possible.

The above limitations can be eliminated if the fine grained control is not a compulsion. Improvements can be made in order to allow only an editing of certain amount in one go using mouse-drag. As long as the pointing device is being dragged aligned with the contour, it gets edited continuously. This should not happen. If there is a limit beyond which the editing is prohibited at a time, it would eliminate the issue of shape distortion. Moreover, the number of pixels by which editing is done should be controlled by the user according to the amount of editing required. These improvements can be made to eliminate the limitations

with existing methods.

V. CONCLUSION

Fibrosis in the myocardium (heart muscle) caused by ischemia of coronary arteries leads to ischemic cardiomyopathy. Increased accumulation of extracellular matrix (ECM) that impacts cardiac function, is the underlying cause of fibrotic heart disease. Contrast enhanced cardiac magnetic resonance images are used by cardiologists to detect fibrosis. This manual process is time consuming. To make a significant reduction in the time taken for the detection, deep learning based models are used to detect fibrosis automatically in the MRI. However due to the imperfections in the models, the detection of fibrosis may not be perfectly accurate. This might prove to be fatal in medical terms.

There are ways of editing the contour to represent the actual region of interest. Using the available methodologies and tools, this task can be accomplished but there are few limitations to it. The deep learning based solutions are efficient in terms of the effort needed to edit the contour. But due to the limitations of the predictive algorithms, there is a possibility that the accurate representation of region of interest is not achieved even after many iterations. This does not mean that the deep learning model is not good. It is simply because of the fact that achieving an accuracy of 100% is not feasible.

Also, from the survey of existing methodologies and the techniques used for segmentation of chambers of heart, it is evident that the models have been trained with a lot of sample MRI images. The techniques have been effectively proven to be accurate, quick, and deployable. The detection of scar tissue without visible symptoms has been made easier. The reach of the systems to the medical practitioners has led to further research paths on deep learning models. Detection and highlighting of the scarred region helps correct analysis of the ailment.

Categorising the ailments has led to simpler diagnoses and quicker treatment procedures. Post the detection, the methods used to correct the highlighting of the region of interest are efficient but not completely accurate. There can be few issues with the handling of contours with the pointing device. The accuracy rate of the systems is reliable to judge the scar fibrosis and help doctors correctly highlight the affected region.. The current visualisation and then the highlighting helps a doctor in his / her clinical decision-making process through the use of the Delta Nudge tool. He/she can actually correct the contour to bring it accurately over the region of interest. This is a major step in correct analysis of the disease. Delta Nudge Tool lets the doctors take this major step without fine control over the pointing device. Thus, this work reduces the work and maximises the output.

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