GeoInterp: Contour Interpolation with Geodesic Snakes

Release 1.00

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July 17, 2006

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Abstract

The process of outlining organs on three dimensional medical images is extremely time-consuming. In this document, we describe a new tool that can interpolate contours and also make them smooth. The tool uses geodesic snakes to perform these functions. The implementation uses The Insight Toolkit and the implementation of geodesic snakes that comes with SNAP.

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1 Introduction and Motivation

Outlining or segmenting organs in three dimensional medical images is usually the first step to some of the image-based diagnostic and curative measures in the clinic. For example, in radiation treatment planning, the segmented organs are used to direct the radiation beams so that the malignant region recieves a large dose whereas the non-malignant tissues are not affected. The process of segmenting organs is usually done manually by an expert and is very tedious and prone to error. At the very least, manual segmentation is needed to produce training samples that are used by more sophisticated methods to automate the process of segmentation.

Any tool that can save the time of the user and help fix minor errors in their segmentations is highly valuable. This tool needs to be pluggable into the user's preferred interactive contour drawing program. In this document, we describe a tool that can interpolate the contours. While doing so, it also makes the result smooth by reducing the jagged nature of the contours drawn by the user.

The basic idea is to save contouring time by allowing the user to draw a few coarsely spaced contours. The tool then generates interpolated contours for the remaining slices. These interpolated slices can then be edited and modified by the user. If necessary, this new set of contours can be sent back to the tool for interpolation and smoothing. In section 2, we give a brief overview of geodesic snakes that are used in our algorithm. This is followed by a discussion of our algorithm in section 3. Finally, in section 4, we discuss our implementation and describe how we have tied it up with PLUNC [1], a radiation treatment planning system developed at the University of North Carolina at Chapel Hill (UNC).

2 Geodesic Snakes

A geodesic snake in 3D is a deformable surface embedded in a three dimensional image. It is initially described by a shape that approximates the object in question. Usually an embedded sphere is used for simplicity. The snake then undergoes deformation by the action of two forces. One of these forces drives the snake to align itself with the intensity edges, whereas the other one tries to make it locally smooth and regular. The former is referred to as image force and is external to the snake, whereas the latter is known as curvature force and is intrinsic to the snake.

In geodesic snakes, computing the external image force involves pre-processing the image in such a way that the snake is repelled by negative intensity regions in the image and attracted by positive intensity regions. An intensity of zero makes the image force locally zero, and in such a region of zero intensity its evolution is completely guided by the curvature forces. The interested reader is referred to Yushkevich et. al [2] for more details. In the next section, we describe how we use geodesic snakes for interpolating and smoothing a partially drawn set of contours.

3 Contour Interpolation

The algorithm can be described by the following steps.

1. An expert draws at least two contours at each end of the object and a few contours in between for every one out of four or five slices.

2. We then create an image and fill it up as described below.

   We first compute a bounding box around the contours. Outside this box, the intensity is set to a negative value, specifically -1. Also, on the image slices with the contours, the outer region is filled with an intensity value of -1, and the inner region is filled with an intensity value of $+1$. On slices where there are no contours, the part of the slice lying inside the bounding box is filled with an intensity value of zero.

   The initial snake is set to the union of the regions with intensities of zero or $+1$ in the synthetic image.

   Two control parameters `PropagationWeight` and `CurvatureWeight`[1] can be adjusted to control the weight of the image force with respect to the curvature force. A relatively higher propagation weight

[1] These and other parameters are configurable through a command file. A sample command file is included with the source code.

prevents the snake from deviating too much from the original contours. It represents the confidence the user has in their segmentation. Thus, the snake's evolution is guided by the contours in the regions where they are present and by the curvature forces where they are not. The result is a small smooth shape that uses the contours drawn by the radiologist as a guide and approximates the organ very well.

3. This pre-processed image and the initial snake is given as input to the snakes implementation used in SNAP [2]. The number of iterations can be controlled by the parameter `SnakeIterations`. This can be set to a small value of around 100 for a quick preview or a large value such as 500 for more stable results.

4. The result is saved as an image and also converted to a BYU tileset. This tileset is run through a smoothing and decimation filter before being saved. The amount of decimation and smoothing can be controlled by another set of parameters.

The steps described till now are performed by the tool included with this document. In Fig. 1, we show the result after a single run of our tool. The interpolated contours match very well with the organ geometry; we show this for a particular slice in Fig. 2.

An interesting way to use this tool is to smooth and fix some errors in manual segmentation. Most contour drawing programs present the user with two dimensional slices of the image to draw upon. It is very tricky to draw contours that are in agreement with the ones on the slices immediately above or below it. The result is noticeable jaggedness in the third dimension as well as some seemingly obvious errors when visualized in three dimensions. These errors usually look like small fins or scales coming out of the object. As the above algorithm uses the initial contours only as a guide, it removes these jagged edges and other errors. In Fig. 3, the green contours are those drawn by the radiologist while the red contours are the result of smoothing. Notice that they are significantly more smooth and at the same time retain some of the sharp features of the object.

In the next section, we describe how we have tied this tool with a particular contour drawing program that comes with a radiation treatment planning system known as PLUNC.

4 Implementation

The tool is implemented in C++ and needs the following tools and libraries.

- Insight Toolkit (ITK) 2.4 or higher,
- InsightSNAP from InsightApplications,
- CMake 2.2 or higher, and
- Visualization Toolkit (VTK) 4.2 or higher.

This tool is currently used with The Plan UNC (PLUNC) radiation treatment planning system to aid in the segmentation of organs in the head and neck region. The radiologist draws the contours in PLUNC and then chooses a menu option to launch the tool. Filters present in between convert the files to a format used by the tool. After the tool has finished, the tileset is conerted to a set of contours and exported back to PLUNC. Inside PLUNC, the radiologist can edit or delete the contours that do not look good and run the tool again if he or she so wishes. The new run will take into account all these changes made by the radiologist.

5 Pros and Cons

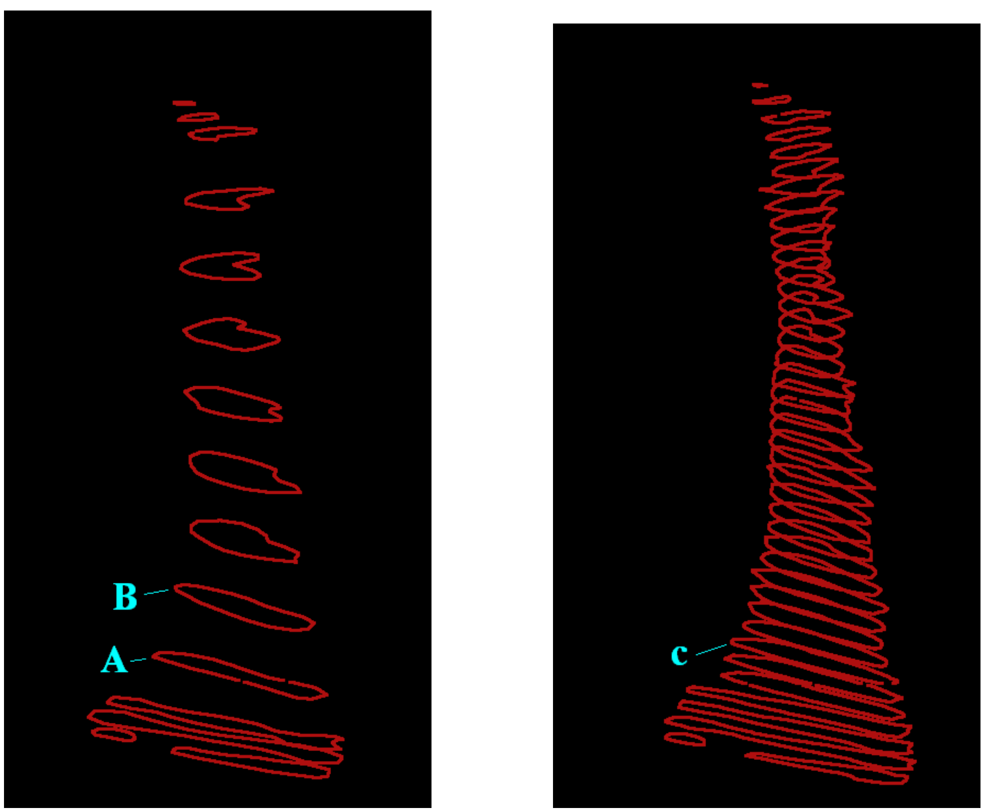
The tool provably saves time, reduces the effort and generates better results than full manual segmentation. This was observed during the segmentation of the organs in the head and neck region. As the tool can be run from a command line and does not require any manual intervention, it can be used for batch processing and can be combined with any other contour drawing program.

The weakness is that the snakes implementation is a little slow so the radiologist has to move onto the next organ while the tool works on the previously submitted one. Also, an opportunity exists to improve the result further by combining the grayscale information with the synthetic image generated by the algorithm with the help of some image composition filter to produce better results.

References

[1] S L Sailer, E L Chaney, J G Rosenman, G W Sherouse, and J E Tepper. Three dimensional treatment planning at the university of north carolina. *Seminars in Radiation Oncology*, 2(4):267–273, 1992. 1

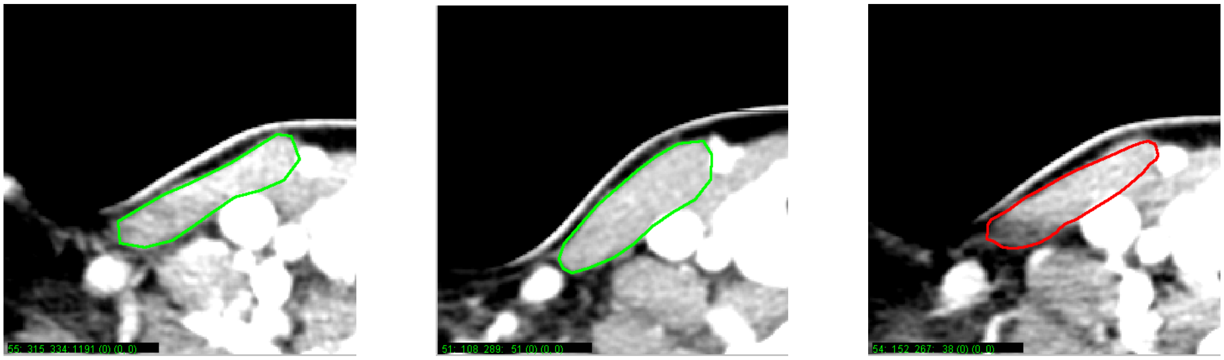
[2] P Yushkevich, J Piven, H Cody, S Ho, and G Gerig. User-guided 3d active contour segmentation of anatomical structures: Significantly improved efficiency and reliability. *Neuroimage Journal*, 31(3):1116–1128, 2006. 2, 3



(a) Set of contours used for interpolation

(b) Result of interpolation

Figure 1: Interpolation in sternocleidomastoid muscle



(a) Slice A from Fig. 1

(b) Slice B from Fig. 1

(c) Slice C from Fig. 1 showing interpolated contour

Figure 2: Interpolation in sternocleidomastoid muscle - two dimensional view of select slices

Figure 3: The result of smoothing a masseter muscle: green contours have been drawn manually, whereas the red ones are the result of interpolation.