Chapter 2

Active Contour Based Segmentation Techniques for Medical Image Analysis

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Abstract

Image processing is a technique which is used to derive information from the images. Segmentation is a section of image processing for the separation or segregation of information from the required target region of the image. There are different techniques used for segmentation of pixels of interest from the image. Active contour is one of the active models in segmentation techniques, which makes use of the energy constraints and forces in the image for separation of region of interest. Active contour defines a separate boundary or curvature for the regions of target object for segmentation. The contour depends on various constraints based on which they are classified into different types such as gradient vector flow, balloon and geometric models. Active contour models are used in various image processing applications specifically in medical image processing. In medical imaging, active contours are used in segmentation of regions from different medical images such as brain CT images, MRI images of different organs, cardiac images and different images of regions in the human body. Active contours can also be used in motion tracking and stereo tracking. Thus, the active contour segmentation is used for the separation of pixels of interest for different image processing.

Keywords: energy constraints, gradient vector flow field, inflation force, geometric measures, icosahedron triangles

1. Introduction

Image processing can be defined as computerised processing of images of different types to obtain the desired output. Image processing makes use of a wide range of techniques to process the input information which is available in the form of an image. Processing of images is carried out by avoiding certain features like noise and signal distortion that affects the information present in the images. The images can be defined in different dimensions which can be used for processing. Segmentation is a part of image processing used for segregation of regions.

Segmentation is the process of separation of required information from a data for further processing. Image segmentation can be defined as the segregation of pixels of interest for effective processing. The main aim of image segmentation is to segment the meaningful regions of interest for processing. Region of interest possesses a group of pixels defined with a boundary and these may contribute to different forms such as circle, ellipse, polygon or irregular shapes. The process of segmentation does not provide information about the entire image rather associates pixel data of only the region of interest. Segmentation is a crucial process in Image analysis because it paves path for future processing of images.

In medical image analysis, segmentation is very much necessary where region of study or research is defined to a particular section of the image. If image segmentation is performed effective, the after stages of image analysis are made easier. Image segmentation provides definite and useful information or data for the high standards of automatic image analysis. Image analysis defines certain objectives for segmentation process:

- Decompose the image into parts for future analysis
- Change in representation
- Region of interest should be simple, uniform and homogenous with smooth boundary

Medical image analysis requires segmentation of images for processing of the region of interest. Different modality of images can be processed and segmented for separating the necessary pixel information. Image segmentation is described as the fundamental process in many computer vision and medical image analysis applications. With the process of segmentation, desired output from the pixels of interest is obtained.

Image segmentation can be classified into different types of algorithm based on the discontinuity and similarity of intensity values. Thresholding, region growing, region splitting, region merging, detection of boundary discontinuities (point, line and edge detection), watershed segmentation and active contours are few examples of image segmentation process. Segmentation can also be performed with the help of feature extraction process from the pixels of the image.

In this chapter, we discuss about an image segmentation technique called active contour models. These models are considered because they help in segmentation of the target object of particular data or information values from an image. Active contour technique is applied for separation of foreground from the background and the segmented region of interest undergoes further image analysis. Active contours are defined models for segmentation of pixels from the required region of interest for which processing is performed to obtain the outcome for research. Active contour models defined below are used in various different fields for image processing. Application of active contour models in medical image processing is very effective, since it separates the necessary pixels from the foreground [1].

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2. Active contour models

Active contour is a type of segmentation technique which can be defined as use of energy forces and constraints for segregation of the pixels of interest from the image for further processing and analysis. Active contour described as active model for the process of segmentation. Contours are boundaries designed for the area of interest required in an image. Contour is a collection of points that undergoes interpolation process. The interpolation process can be linear, splines and polynomial which describes the curve in the image [2]. Different models of active contours are applied for the segmentation technique in image processing. The main application of active contours in image processing is to define smooth shape in the image and forms closed contour for the region. Active contour models involve snake model, gradient vector flow snake model, balloon model and geometric or geodesic contours.

Active contours can be defined as the process to obtain deformable models or structures with constraints and forces in an image for segmentation. Contour models describe the object boundaries or any other features of the image to form a parametric curve or contour. Curvature of the models is determined with various contour algorithms using external and internal forces applied. Energy functional is always associated with the curve defined in the image. External energy is defined as the combination of forces due to the image which is specifically used to control the positioning of the contour onto the image and internal energy, to control the deformable changes [3]. Constraints for a particular image in the contour segmentation depend on the requirements. The desired contour is obtained by defining the minimum of the energy functional. Deforming of the contour is described by a collection of points that finds a contour. This contour fits the required image contour defined by minimising the energy functional.

For the set of points in an image, the contour can be defined based on forces and constraints in the regions of the image. Active contours are used in various applications in the segmentation of the medical images [11, 17]. Different types of active contour models are used in various medical applications especially for the separation of required regions from the various medical images. For example, a slice of brain CT image is considered for segmentation using active contour models. The contour of the image defines the layers of the region in the brain which is shown in the **Figure 1**.

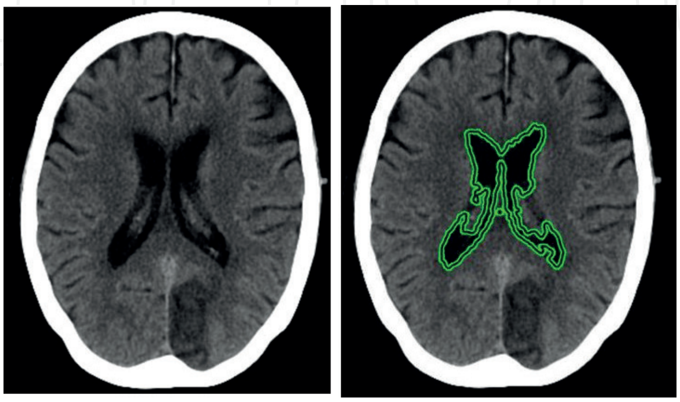

Figure 1. Segmentation of brain CT image using active contours.

Active contours can also be used for segmentation of 3-D images derived from different medical imaging modalities. 2-D slices of image data are used for the separation of target object from the 3-D images. These 2-D slices of images in all directions along with the segmented target region are subjected to 3-D reconstruction to segregate the regions. Mesh model of the 3-D image is designed before applying active contour model. The mesh helps in the formation of deformable contours of the target object in the directional 2-D slices of the 3-D images [14].

Different types of images from various 3-D imaging modalities like MRI, CT, PET, SPECT can be segmented and processed with these active contour models. The early diagnosis and detection of abnormalities in the target regions can be performed with the help of active contour models in 3-D imaging. Detection of target regions in the 3-D images enables in accurate description and sectional study of the regions [8]. Here for example, consider the head CT image of eight 2-D slices is subjected to 3-D segmentation using active contour models. In this process, mesh is designed for the head CT image based on which segmentation of the target region is performed. The mesh is formed with the help of the volumetric pixel values in all the x, y and z directions. The 2-D slice of the head CT image and mesh model designed for that 2-D slice of head CT image in all directions is defined in **Figure 2(a)** and **(b)** respectively. In **Figure 2(b)**, the axes of the mesh model describe the volumetric values (voxels) in all three directions representing the head CT image.

3-D segmentation of the image for every slices of the 2-D image is carried out through iterative applications of the active contour models. This segmentation process helps in segmenting the target region in all the slices. In this example, all the slices of head CT image undergo iterative contour segmentation for separation of the thoracic cavity [13]. In **Figure 3**, the iterative segmentation of each and every region of the thoracic cavity from the head CT image is shown. Segmentation of fine structures from the target object in an image is possible with these active contour models. Pham et al. describe the methods for medical image segmentation.

The application of active contour models for segmentation is used in various medical image processing techniques. 2-D and 3-D segmentation of the medical images is performed to obtain

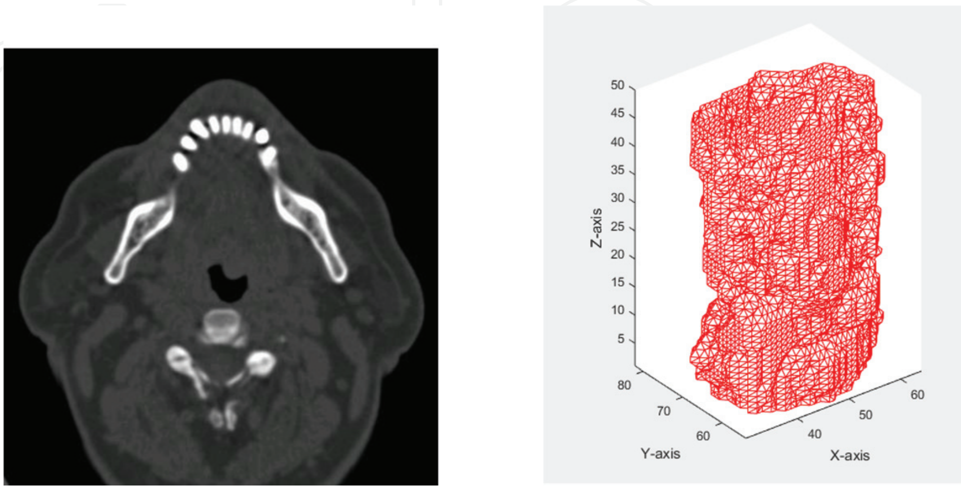

Figure 2. (a) 2-D slice of head CT image and (b) mesh model for the 2-D slice of head CT image.

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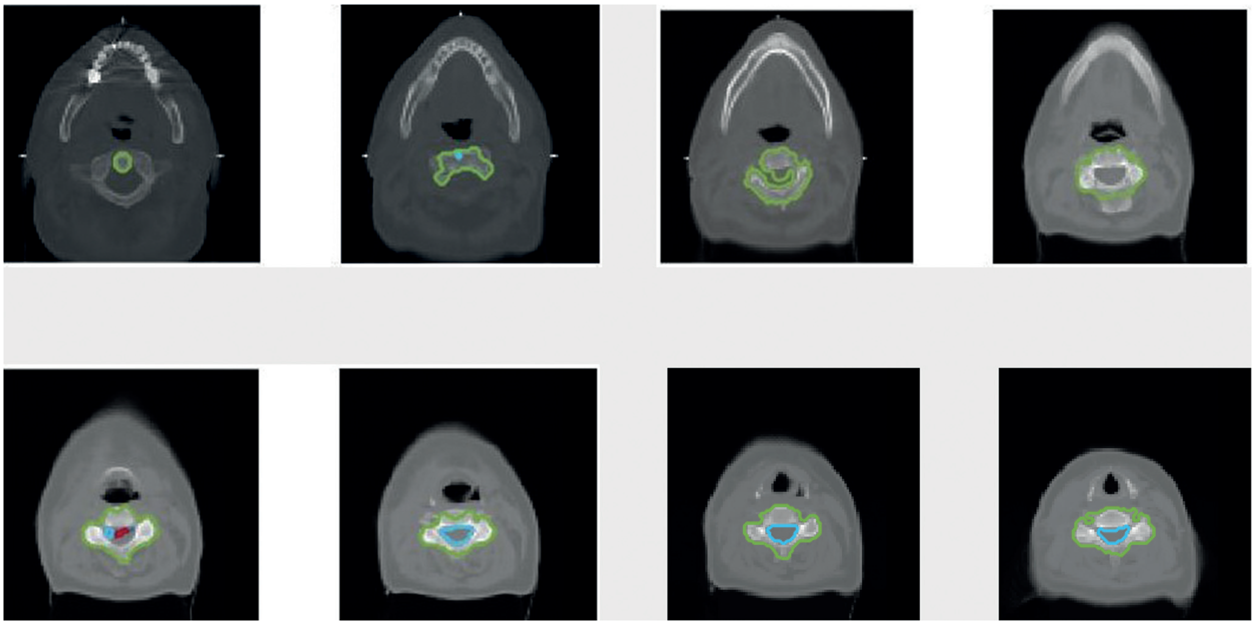

Figure 3. Iterative 3-D segmentation of head CT image using active contours.

the exact target object for identification, detection and diagnosis of any abnormal or unwanted changes in the human body. 2-D active contour models are used for segmentation of specific target area which possesses pixel information and in 3-D process of forming contour, the specific regions of voxel information are determined. Based on the information provided by the segmented region, further processing of the images occurs [16]. Active contour models are also used in 4-D segmentation such as motion tracking, stereo tracking of the movement of the internal regions [19].

Thus active contour models are used in various medical applications. The medical images from different modalities are considered for the description of active contour model and its types [28]. Active contour models used for medical image segmentation and processing are defined in this chapter. In the field of medicine, segmentation of target objects with accurate boundary lines is very much necessary for diagnosis and detection of any abnormalities in the body. This kind of segmentation is carried out with these models. In order to understand the application of active contour models in the field of medicine, these images are obtained from different authorised and standardised databases.Thus these medical images are considered to illustrate use of medical image processing. Traditional model and all the extended versions of the active contour models are described below in this chapter.

2.1. Snake model

Snake model is a technique that has the potential of solving wide class of segmentation cases. The model mainly works to identify and outlines the target object considered for segmentation. It uses a certain amount of prior knowledge about the target object contour especially for complex objects. Active snake model also called snakes generally configures by the application of spline focussed to minimise energy followed by various forces governing the image. Spline is a mathematical expression of a set of polynomials to derive geometric figures like curves. Spline of minimising energy guides the constraint forces and pulled with the help of internal and external image forces based on appropriate contour features. Snake model enacts deformable model to an image through energy minimisation. This model commonly uses cubic polynomial though higher order polynomials can be incorporated but usually avoided due to several undesirable local properties to confront with. Snake works efficiently with complex target objects by breaking down the figure into various smaller targets [1, 9].

Snake model is designed to vary its shape and position while tending to search through the minimal energy state. Snake propagates through the domain of the image to reduce the energy function, and intends to dynamically move to the local minimum. Snake is expressed by Eq. (1). The parametric form of the curve is exploited in the Snake model that has more advantages than utilising implicit and explicit curve forms

$$v(s,t) = \left(x\ (s,t), y(s,t)\right) \tag{1}$$

where x and y are the coordinates of the two-dimensional curve, v is spline parameter in the range 0–1, s is linear parameter ∈ [0,1] and t is time parameter ∈ [0, ∞].

The forces in snake include external forces as well as image forces that helps in feature identification. When the snake model moves around a closed curve, it moves with the influence of both internal and external energy to keep the total energy minimum. The total energy of active snake model is a summation of three types of energy namely (i) internal energy (E_i) which depends on the degree of the spline relating to the shape of the target image; (ii) external energy (E_e) which includes the external forces given by the user and also energy from various other factors; (iii) energy of the image under consideration (E_I) which conveys valuable data on the illumination of the spline representing the target object. The total energy defined for the contour formation in the snake model is given by Eq. (2).

$$E_T = E_i + E_e + E_I \tag{2}$$

$E_{internal}$ describes the internal energy which defines piecewise smoothness constraints in the contour, where α decides on how far the snake will be extended and the capacity of elasticity possible for the snake. β decides on the rigidity level for the snake. The internal energy is given by Eq. (3).

$$E_{internal} = \sigma\left|\frac{\partial v}{\partial s}\right|^2 + \beta\left|\frac{\partial^2 v}{\partial s^2}\right| \tag{3}$$

External energy constraints are mainly used to define the snake near the required local minimum. It may be described using high level interpretation and interaction.

$$E_{image} = w_1 I(x,y) + w_2\left|\nabla I(x,y)\right|^2 + \dots, \tag{4}$$

The contour of the target object is shown in the above Eq. (4), where w_1 is called the line efficient and w_2 is called the edge efficient. According to the higher values of w_1 and w_2, snake

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will align itself to darker pixel regions in the case of positive value and it progresses towards the bright pixels when the value is negative. Snake model used for segmentation of various types of images.

The applications of active snake model are increasing in a tremendous manner especially in the various imaging fields. In medical imaging field, snake model is used segment one region of image which has special features compared to other regions of the image. Different applications of traditional snake model in medical imaging are optic disc and cup segmentation to detect glaucoma, cell image segmentation, vascular region and various other regions segmentation for diagnosis and study of disorders or abnormalities. For example, a slice of chest CT image is considered for segmentation using snake model. Chest CT image possesses the sections of internal organs like lungs and heart. In this image, snake model is applied for the segmentation of left lung from the chest image which is shown in **Figure 4**. Contour is developed around the left lung which can be used for further processing.

Boscolo et al. define the use of chest CT image for segmentation using traditional snake active contours. Specific region of segmentation is possible with these traditional active contour methods [26]. In the above example, specific lung region is separated from the image for extraction of features and diagnose the region whether it possesses any abnormalities or not in a computerised manner. The traditional method of active snake model has several inefficiencies like insensitivity to noises, false contour detection in high complex objects which are solved in advanced versions of contour methods.

2.2. Gradient vector flow model

Gradient vector flow model is an extended and well-defined technique of snake or active contour models. The traditional snake model possesses two limitations that is poor convergence performance of the contour for concave boundaries and when the snake curve flow is initiated at long distance from the minimum. Gradient vector flow model as an extension makes use of gradient vector flow field as energy constraint to define the contour flow.

Gradient vector flow (GVF) field is determined based on the following steps. The primary step is to detect the edge mapping function f(x, y) from the image I(x, y). Edge mapping function for binary images is described by Eq. (5), where $G_\sigma(x, y)$ is a 2D quassian function with the statistical parameter, standard deviation σ.

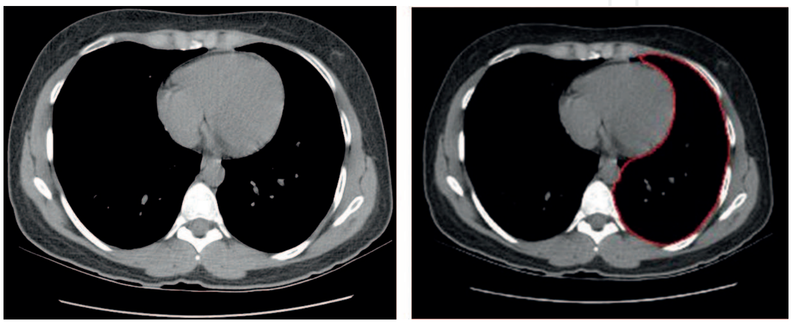

Figure 4. Segmentation of chest image using snake model.

$$f(x, y) = -G_\sigma(x, y) * I(x, y) \tag{5}$$

Edge map function for grey-scale images is given by Eq. (6) where the gradient operator is ∇

$$f(x, y) = -\left|\nabla\left[G_\sigma(x, y) * I(x, y)\right]\right|^2 \tag{6}$$

Gradient vector flow field is the equilibrium solution that reduces the functional energy. The functional energy possesses two different terms such as smoothing term and data term which depends on the parameter μ. The parameter value is based on the noise level in the image that is if the noise level is high then the parameter has to be increased. The main problem or limitation with gradient vector flow is the smoothing term that forms rounding of the edges of the contour. Therefore, increase in the value of μ reduces the rounding of edges but weakens the smoothing condition of the contour to a certain extent. The gradient vector flow is defined by the energy functional Eq. (7).

$$\varepsilon = \iint \mu\ \left(\ {u_x}^2 + {v_x}^2 + {v_y}^2\right) + |\nabla f|^2 |g - \nabla f|^2\ dx\ dy \tag{7}$$

In this equation, g describes the gradient vector flow which can be derived based on the Euler equations. This equation defines the Laplacian operator that is defined by two different Eqs. (8) and (9).

$$\mu\nabla^2 u - (u - f_x)\left({f_x}^2 + {f_y}^2\right) = 0 \tag{8}$$

$$\mu\nabla^2 v - (v - f_x)\left({f_x}^2 + {f_y}^2\right) = 0 \tag{9}$$

Computational solutions to calculate f_x and f_y in the equation are obtained by using common gradient operators such as sobel, prewitt, or isotropic operators. Based on these parameters the gradient vector flow field is defined. After the determination of GVF field g(x,y) it is used to replace the energy constraints in the traditional snake model. With these constraints, the continuous computation of the curve flow occurs iteratively for structural defining of the contour [4].

Gradient vector flow model can be used in all higher dimensions based on the minimum of the energy function. In two-dimensional image regions, a time variable t is introduced for solving the Euler equations. The Euler equation can be used to define entire target object as a deformable contour through iteration towards a steady state value. Thus the equations obtained are used instead of the external force in the traditional snake model. Contour of the target object from the image is defined based on the edge mapping function and gradient vector flow field. The gradient vector flow model is used for the segmentation of exact target region compared to the snake model.

The gradient vector flow model is an extended version of snake model used in various image processing applications especially in medical image processing. In medical imaging, the segmentation of regions with specific parameters is carried out with the help of active contour models. Because these models develop a contour around the target object and segregates it from the image. The segmented image possesses only the required information of the target object [10].

For example, the breast mammogram obtained from a standard database undergoes gradient vector flow active contour model. This model defines the boundaries of the breast region and regions of calcification in the mammogram image section. The segmentation of breast mammogram with the highlighted calcification regions is shown in **Figure 5**. In the mammogram image segmentation, the calcified regions are highlighted with the gradient vector flow contours which help in computerised early diagnosis and detection of calcification in breast regions. Ferrari et al. describes the segmentation of boundaries of the calcified region in breast mammogram [27]. Gradient vector flow field also uses the minimum energy function for segmentation of cardiac and brain regions. This model helps in motion tracking of the various regions in the human body especially pumping action of the heart and muscular activities of various regions.

Gradient vector flow model is used for all types of images obtained from different imaging modalities. Thus extended version of snake in the form of gradient vector field is used in all medical image processing applications.

2.3. Balloon model

A snake model is not attracted to distant edges. The snake model will shrink inner side, if no substantial images forces are acting upon it. A snake larger than the minima contour will eventually shrink into it, but a snake smaller than minima contour will not find the minima and instead continue to shrink. In order to overcome the limitations of snake model, balloon model was introduced in which inflation term is induced into the forces acting on the snake [3]. The inflation force can overpower forces from weak edges, amplifying the issue with localisation of initial guess. The additional inflation force is given by Eq. (10) with $\vec{n}\,(s)$ as normal unity vector of the curve and k_1 as magnitude of the curve.

$$F_{inflation} = k_1 \vec{n}(s) \tag{10}$$

Here k_1 should possess similar magnitude as that of the image normalisation vector k and must have smaller value that allows the forces in the image edges to adjust with the inflation force given additional to the internal and external energy.

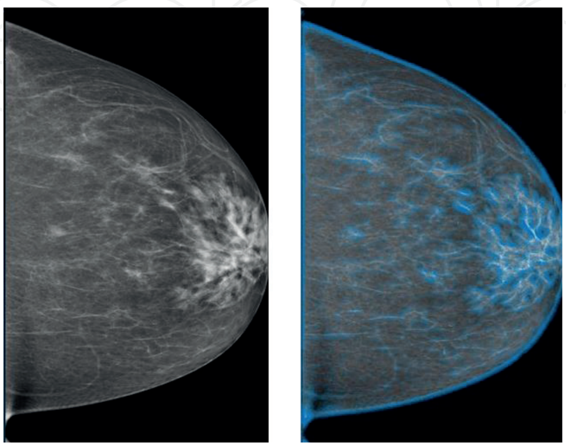

Figure 5. Breast mammogram segmentation using gradient vector flow (GVF) model.

An overview of this algorithm, it will locate an area in the volume, then place a icosahedron in that area such that it contains no points. Expand (or) subdivide the icosahedron so that it approximates the volume. Thus the algorithm starts with a small icosahedron inside the object. Each vertex is connected to its neighbours by springs that inflate each triangle or segment along the normal based on inflation pressure inside the sphere. With respect to depth, start with range images where the images are joined to a single point cloud. Manually insert the starting point of icosahedron hence, if it is difficult to compute do it by hand. Then place the icosahedron in a fixed location to develop a contour.

The major two forces act on each vertex. Inflation force is used to push the vertices out and spring force is calculated based upon one ring neighbourhood of each vertex. Inflation force is calculated based upon normality of value of points in the contour. Expansion algorithm is a set of instructions used to create a front of the icosahedron which has all the faces. At first, insert the front section into the instructions queue. For each vertex in the front, it is used to calculate the spring force and inflation force. Now, compute the new location. Compute nearest point from the dataset. Then, update the co-ordinator. Later, discard the anchored triangles in the region of interest. The expanding triangles will reconstruct the surface less accurately due to their large size. While expanding the spring forces between vertices become very large. Subdivide triangles to reduce force. Triangles are subdivided so that no T shaped junctions exist in forming the contour. Long and skinny triangles are reconnected to be wide and short. A triangle becomes anchored once it reaches the surface of the point cloud. This is determined by testing for intersection with the point set based on vertex normal. Once a triangle is anchored it has no longer moves, all the vertices are stationary [13].

Three issues arise from using the balloon model. Instead of shrinking, the snake expands into the minima and will not find minima contour smaller than it. The outward force causes the contour to be slightly larger than the actual minima. This can be solved by decreasing the balloon force after a solution has been found. Computation is done by performing the intersection of a ray with a range image. Iterative process requires refinement of approximation. All range scans have to be looked to get a result. Holes are handled similarly to anchoring process. Noise is broken into two categories namely misalignment of range scans, scan errors mostly outliers. Both these areas are handled by intersection algorithm and filtering.

Balloon model is used in the segmentation of different medical images. The application is mainly used for presenting a novel model for segmenting 2-D image and reconstructing 3-D meshes which guarantees a waterlight mesh. In 2-D segmentation, the contour separates the region of pixels with specific feature. Contour is formed for separation of lesions, tissue regions, infected cells, and parasites from the images. 3-D mesh formation is mainly used in the reconstruction of 3-D images from different imaging modalities [10]. 3-D models can also be designed for artificial implants using mesh technique based on the inflation balloon force.

One of the examples for 2-D segmentation of images using balloon model is skin lesion segmentation. The segmentation of lesion from the dermal image is shown in **Figure 6**. In general, skin lesion segmentation from the dermal images is very much necessary for the early detection of skin cancer which is becoming predominant in all tropical countries. Thus balloon model is commonly used for segmentation of lesions because the inflation force defines an

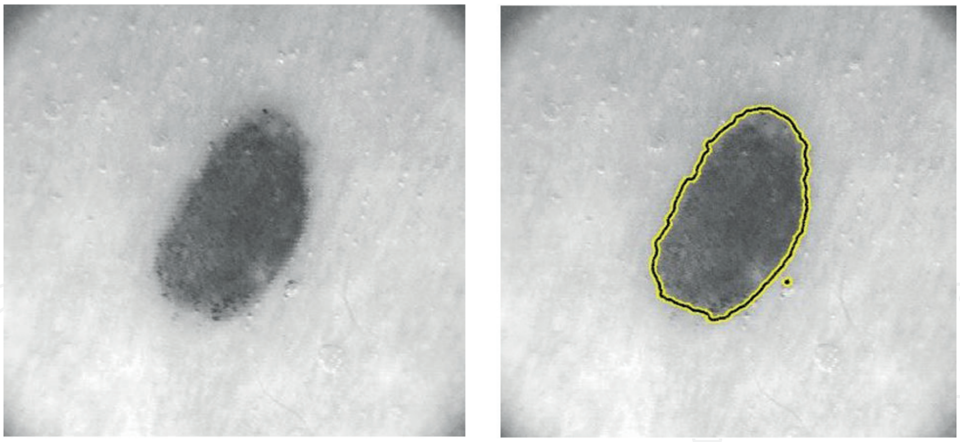

Figure 6. Skin lesion segregation from the dermal images using balloon models.

accurate contour [31, 32]. These contours are used for further processing and prediction of skin cancer. The main disadvantage of the balloon model is slow processing that it is difficult to handle sharp edges and it has a manual object placement. Balloon model is widely used in analysing the extraction of specific image contour.

2.4. Geometric or geodesic active contour models

Geometric active contour or geodesic active contour (GAC) is a type of contour models that modifies the smooth curve defined in the Euclidean plan by moving the points of the curve perpendicular. The motion of the points is at a speed proportional to the curvature of the region in the image. Contours are described based on the geometric flow of curve and detection of objects in the image. Geometric flow includes both internal and external measures of geometry in the region of interest. Geometric alternative for snakes is used in the process of detection of objects in an image. These contour models largely depend on the level set functions that describe the specific regions in the image for segmentation [5, 6].

Geometric contours define a initial curve C_0 with the flow of geometry given by the planar contour evolution Eq. (11) with g as the edge indicator scalar function, $k\vec{N}$ as curvature vector, $\vec{N}$ as normal vector to the curve and v as arbitrary constant.

$$C_t = g(C)(k - v)\,\vec{N} \tag{11}$$

The curve evolution continues to propagate until the g value becomes zero that indicates the curve reaches edge of the region or object required from the image. In this method of contour model, snake parameter is replaced by Euclidean arc length which is defined as given in Eq. (12)

$$ds = |Cp|\,dp \tag{12}$$

Euclidean arc length describes the irregular length of the curve based on the curvature and the energy forces. Internal and external energy forces are coupled together which leads to minimum of the functional derivative of geometric curve flow. Differential evolution of curvature of the region in an image is given by the Euler Lagrange Eq. (13) in which C is defined as signed distance function [20].

$$\frac{dC}{dt} = \left(g(C)k - \left\langle \nabla g, \vec{N} \right\rangle\right) \vec{N} \tag{13}$$

Geometric active contour depends on the level set function and geometric planar curve evolution which describes the region for segmentation. By adding an area of minimising region (balloon force), propagation of contour occurs internal by minimisation of the interior energy. Therefore, Euler Lagrange equation is determined as the deepest descent and is given by Eq. (14).

$$\frac{dC}{dt} = \left(g(C)k - \left\langle \nabla g, \vec{N} \right\rangle - \sigma g(C)\right) \vec{N} \tag{14}$$

Contour models use the energy forces for geometric flow curve description. Geometric contours can be obtained based on regions and edges in the curvature of the image [12].

Edge-based geometric active contours define a geometric flow curve evolution depending on the gradients of edges or boundaries in the image that undergoes contour segmentation. Edge-based geometric models possess fast computation speed and can simultaneously segment different regions of different intensities. In some regions, penetration of gap in-between the curvature occurs due to large gradient magnitudes. These geometric models are sensitive to local maximum gradient computation which is used in defining the contours. These limitations can be fixed by increasing the curvature weight and advection weight respectively.

Region-based geometric contour models are based on either the variance inside and outside contour or the squared difference between average intensities inside and outside the contours along with the total contour length. This type of contour model supports different image properties not only edges which may include texture and other geometrical features. In these contours, computation of multiple groups or segments is not possible but less sensitive to noise [15].

Geometric active contours are mainly employed in medical image computing especially in image-based segmentation. In this, image from any imaging modality is considered for segmentation, to study, process and analyse the regions of interest. These regions may be described as any abnormality formed in the internal regions or organs of the human body like blood clots, injuries, lesions, cell abnormality, metabolic interruptions, biomolecule disruptions and so on. Metabolic changes in the regions or organs can be studied with the help of geodesic contours. Geodesic or geometric contours are mainly based on the geometric measures, and curvature flow based on segmentation process occurs. In this example, fundus image of the eye is segmented with the geometric measures that describes the curvature of the eye ball, optic disc localisation and path of the fine nerve endings. Fundus image mainly contributes to the curvature and position of the optic disc.

In this, geometric flow defines the curvature of eye ball, so abnormalities based on curvature can be obtained. Stąpor et al. define the fundus eye image segmentation with different techniques. One among them is geodesic active contour model [30]. Optic disc localisation is performed with the mapping level set functions. The optic disc is segmented as an elevated structure possessing the fine retinal vessels and nerve endings [34]. Contour of each and every fine structure in the image is described through geometric or geodesic active contours [7, 29]. This property of the active contour model can be used more effectively in 3-D image construction and mapping. In **Figure 7**, segmentation of fundus image for optic disc localisation is shown.

Recent applications of geometric or geodesic active contours include 3-D medical image segmentation and 3-D motion tracking and segmentation of moving objects in medical imaging. Segmentation of medical images using geometric or geodesic active contour models has increased largely for accurate separation or segregation of required regions. Thus fine and absolute details of the medical images can be obtained and even three-dimensional data can be derived using this geodesic contour model.

In general, active contour models possess different extended versions with change either in the form of energy constraints or forces. New contour models are designed for the segmentation of absolute details of the image. One of the active contour models in which the constraints and energy forces are used to develop a contour around the edges of the target object. In order to study the membrane structures, edge-based contour models are used. Region-based active contour models are developed for 3-D segmentation of images. These contour models develop contour boundaries with energy forces required for the particular region of interest [23].

Fuzzy energy-based active contour models are designed for segmentation process in which fuzzy logic is applied by changing the localised membership values for each iteration. These contour models are used for multiple object segmentation [21]. 3-D adaptive crisp active contour model is a newly developed technique for 3-D segmentation of medical images especially used for CT lung image segmentation. Adaptive energy constraints are used for automatic initialisation of deformable contours [24]. Other extended version of active contour model is designed based on the local and global details of intensity in an image. The statistical numerical and level set function determines the intensity inside and outside the contour of the image. With less iteration, these contour models can be used for medical image segmentation [25, 34].

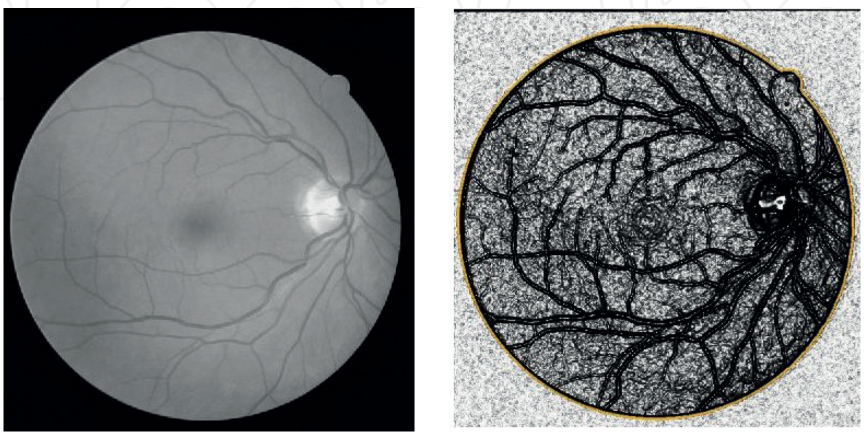

Figure 7. Fundus image segmentation using geodesic active contours.

Frequency-tuned active contour model uses predefined frequency filters to describe the process of segmentation. Gaussian difference is used to remove high range of noise and intensity variations which are obtained using region-based active contour models. This contour model allows selective segmentation and can effectively segment the near texture regions in an image. The contour models are very useful in processing various image datasets and especially for segmentation of real-time optical coherence tomography images [22]. Thus there are different types of extended active contour models used in various image processing applications.

Active contour models of various different forms are defined in this chapter to illustrate the process of target image segmentation. These models are mainly used to form a deformable contour around the target objects more effectively. Energy forces describe a specific contour for the required region based on various features. This type of image segmentation technique is used in different applications. Especially in the field of medical imaging, segmentation of particular regions is very necessary for diagnosis and detection of abnormalities. Active contour models are best suitable for target object segmentation.

3. Conclusions

Segmentation is a technique to describe, define and segregate regions of interest. Image segmentation is a process mainly to derive the region, curvature or contour of the required targeted region from the image. Segmentation in an image depends on various features and parameters. Active contour models are defined for image segmentation based on the curve flow, curvature and contour to obtain the exact target region or segment in the image for future analysis and processing. Contour models are used in processing various images from different modalities. Active contours segregate the regions of required pixel intensities based on the energy forces and conditions. Different types of active contour models are used in the process of segmentation.

In this chapter, active contour models used for the image segmentation process is described in detail. The different types of active contour models defined are traditional snake, balloon, gradient vector flow and geodesic active contour model. In which snake model depends on the internal and external forces exerted by the contour curve. Balloon model similar to snakes uses an additional inflation force to define the curvature. In gradient vector flow model, the contour is described based on the gradient vectors of the curve flow. Geometric model defines the contour using the geometric flow curve and energy forces.

Active contour models are applied in different fields for image segmentation process. In medical imaging field, segmentation of images from different regions of the human body is carried out to study, analyse, diagnose and detect abnormalities. Lesions, blood clotting, abnormal outgrowths, cysts, tumours, cancer cells, small aneurysms, inflations and various other diverse abnormalities can be segmented from the medical images for easily analysis and diagnosis [18]. The application of each and every active contour model described in this chapter is related to medical image processing. Medical images from different modalities are considered for the description of the contour models.

3-D segmentation of the contours defined in the target region can be used for further construction and analysis of 3-D images [33]. Active contour models are also useful for mesh formations. These formations help in designing 3-D structures and models. 2-D segmentation of active contour models is more elaborately described in this chapter of image segmentation process. Each active contour model is illustrated with an example describing the segmentation process and algorithms in the field of medical imaging. Different medical images are defined in the examples to provide a clear understanding about the active contour models. Active contour models of different types are used for image segmentation in the various field but widely used in medicine for the early diagnosis and detection of abnormalities in a computerised manner. Thus automatic segmentation of the medical images for diagnosis and study is performed with the active contour models.

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