Abstract—Soft tissue sarcomas are malignant tumors which is difficult to control in soft tissue part of the human body. The effects of the tumor in the body is very difficult to predict for experts. The size and location of the tumor mass is required to detect by an accurate segmentation method. Soft tissue sarcoma image segmentation plays an important role to determine more accurate diagnosis from magnetic resonance images (MRI). In this study, optimized Otsu threshold based preprocessing and post-processing method are proposed for STS segmentation on 9 MRI images which consist of malignant tumors. Four well-known optimization algorithms (Particle Swarm Optimization, Differential evaluation, Whale Optimization and Grasshopper optimization) are used for optimization of Otsu method. The proposed segmentation method offers high robust performance on MRI images.

Keywords—Segmentation, Soft Tissue Sarcomas, Otsu Threshold, Optimization.

I. INTRODUCTION

Soft tissue sarcomas (STS) in malignant lesion group may occur in various regions of the human body such as muscle, fat, nerves and vessels. Also, it can be occurred in various types as fibrosarcomas, leiomyosarcomas, liposar-comas, synovial sarcomas, angiosarcomas, malignant peripheral nerve sheath tumors, gastrointestinal stromal sarcoma [1]. Especially, STS has been usually seen in extremities. STS tumor ranges from 1.8 to 5 per in 100,000 per year in accordance with international standards. In 2016, the United State had 12,310 new and 4,990 death cases of STS which were identified [2]. When the statistics in recent years are analyzed, it can be observed that about half of STS patients die due to poor prognosis with less therapeutic options [3].

It is assumed that same histological subclasses of STS have several clinical response. Heterogeneity feature of tumors is a major obstacle in the treatment of patients with STS. Heterogeneous responses to therapy can even be seen in different regions of the same tumor. For this reason, the unfavorable biological properties have considerably effect on the treatment success. Surgery, chemotherapy, radiotherapy and biological therapy are current main treatments which are conservative due to great pain to the patients. Radiation and chemotherapy methods are very effective in the diagnosis of these heterogenetic regions. Thanks to detection of the tumor biologic features from MRI, physicians are able to determine the most effective method. In addition, early prognosis and treatment are essential to good health. Therefore, this allows more specific therapy rather than unique one fits all approach [4].

On the other hand, surgical resection is a well-accepted methods for tumor therapy. Tissue biopsy is an available method for detection of tumor, but it causes a limited accuracy and long period of processing procedure [5]. At the beginning of treatment, biological imaging of tumor provides effective prognosis for surgeons. Radio frequency ablation is an alternative therapy to obliterate STS tumors [6].

Thresholding is a vital part of segmentation operation and object detection. Distinct curiosity
based on Shannon theory about entropy strategy [7]. An adaptive segmentation method is proposed for EM images [8]. Also, spatial depth in-homogeneity was used for estimation of bias area. Recently, classification of brain tissues in MRI has been implemented via an automated decision tree method. Hidden Markov model is suggested for automated scorching spot detection and physique PET graphic segmentation [9]. A tabu search based on HMRF-EM framework was designed to estimate preliminary parameters [10]. Fuzzy level set method is modified with locally regularized evolution on the purpose of simplifying segmentation on medical images [11]. Fuzzy C means clustering algorithm is combined with metaheuristic optimization methods for segmentation of brain MRI images [12]. Spatial fuzzy C mean clustering method is used for noise-robust image segmentation in real time [13]. On the other hand, several studies have recently been conducted on classification of STS stage. Two different types of soft tissue tumor, a benign and malignant, were classified by using machine learning methods [14]. Different types of tumors were segmented via STS features extracted from T1-weighted MRI images in classification algorithm [4]. Thanks to those properties obtained using the ratio size of radiologically-defined habitats and signal intensities, it is aimed to classify metastatic and necrotic tumor [15]. Metaheuristic algorithms can be classified into three main categories: Evolutionary, Physics based and Swarm intelligence algorithm. Evolutionary algorithms are based on the evolutionary developments in nature. These evolutions are mathematically formulated in order to be coped with contemporary problems. Genetic algorithm was proposed as the first example of evolutionary algorithms by Holland in 1992 [16]. Then, Differential Evolution, Biogeography-Based Optimizer, Genetic Programming and Evolution Strategy are given some examples of latter evolution algorithms [17]. Physics based intelligence algorithms, which are Gravitational Search, Charged system search, Artificial Chemical Reaction, Black Hole, Ray, Small-World, Galaxy-based Search and Curved-spaced algorithm, are inspired from rules of basic applied science [18]. Finally, metaheuristic algorithms converges the best solution by means of imitating the social behavior of swarm. Particle Swarm Optimization, Ant colony, Artificial Bee Colony, Bat Algorithm, Whale optimization and Grasshopper Optimization Algorithm are some main examples of this category [19].

The paper includes five sections. It is started with introduction of STS in Section I. proposed method will be presented for processing and segmenting the view of region in the image. Also, the algorithms used to optimize the threshold value are discussed in Section II. The segmentation results are discussed in Section III. The conclusion and future work are summarized in Section IV.

II. MATERIAL AND METHODS

A. Image Preprocessing

Image preprocessing approach is applied for reduction of image noise because most of the medical images have more noise. The noise in the image should be removed for successful segmentation. For this, image pre-processing is applied first. In the pre-processing step, image normalization processing and noise reduction processing are applied to leg images. Eq. 1 is used to normalize the image.

\[
I_{\text{Norm}}(i, j) = \left( \frac{255}{\max_i - \min_i} \right) \left( I(i, j) - \min_i \right)
\]

\(I_{\text{Norm}}\) is the normalized image, \(\max_i\) and \(\min_i\) are maximum and minimum values of image, respectively and \(I\) is input image. After the normalization process, the noisy image is ready to be cleaned. The most important factor in noise removing process is knowing the noise characteristics and noise distribution. Each noise type is cleaned in different ways. In this study, a median filter [20] was used to clean the noises. The resulting images in pre-processing are shown in Figure 1.

![Fig. 1 Noise removing, a) normal leg image, b) cleaned image](image-url)
B. Otsu Thresholding Method

Image segmentation is very important for detection and estimation of tumor in MRI. Otsu thresholding method is appropriate solution to find optimal threshold value for segmentation of tumors. It is also able to select the optimum gray threshold value via using gray histogram map. After using otsu threshold method, the image is converted to binary image by using Eq. 2.

\[ g(x, y) = \begin{cases} 1; & f(x, y) \geq T \\ 0; & f(x, y) < T \end{cases} \]  

(2)

\( T \) is the threshold value of MRI. When it has constant value, it is called as the global threshold. Otsu method searches optimal threshold value in order to obtain intra-class variance. Therefore, this threshold value is calculated by weighted sum of variances in two binary classes as follows:

\[ \sigma^2 = \omega_0\sigma_0^2 + \omega_1\sigma_1^2 \]  

(3)

\[ \omega_0 = \sum_{q=0}^{L-1} p_q(r_q); \quad q = 0, 1, 2, \ldots, L-1 \]  

(4)

\[ \omega_1 = \sum_{q=0}^{L-1} q^2 p_q(r_q) \]  

(5)

\[ \mu_0 = \sum_{q=0}^{L-1} q p_q(r_q) / \omega_0 \]  

(6)

\[ \mu_1 = \sum_{q=0}^{L-1} q^2 p_q(r_q) / \omega_0 \]  

(7)

\[ \mu_T = \sum_{q=0}^{L-1} q p_q(r_q) / \omega_1 \]  

(8)

\[ p_q(r_q) = \frac{n_q}{n} \]  

(9)

\( n \) represents the total number of pixels in MRI. \( L \) is maximum gray level in the image. \( n_q \) is total number of gray level pixel and on top of that \( r_q \) denotes gray level.

C. Optimization of Otsu Threshold Algorithm

Great strides in optimization algorithms provides significant advantages to solve problems. Especially, they have ability to reach global solution without converging to local solutions. Also, the other advantages are simplicity and flexibility. Particle Swarm Optimization (PSO) is an stochastic optimization algorithm. PSO uses a simulation of the behavior of swarm individuals in nature [21]. Global best position is converged by using swarm intelligence.

Differential Evolution (DE) was proposed as a stochastic, population based optimization algorithm by Storn and Price in 1996 [22]. In multidimensional search space, DE searches the best chromosome via the principle of survival. It has three main operations in one iteration such as mutation, cross-over and selection. Firstly, randomly selected genes in chromosomes are mutated. Thereafter, cross-over occurs between the chromosomes that have undergone mutation and gene transitions. Finally, the best individuals from the chromosomes are selected.

The Whale Optimization Algorithm (WOA) is a contemporary examples of metaheuristic optimization methods. WOA uses the hunting strategy of humpback whales which has the special foraging behavior as bubble-net feeding method while they are hunting small fish swarm around sea surface [23]. The WOA hunting mechanism includes in three main mathematical models such as Encircling prey, Bubble-net attacking method and Search prey.

Grasshopper Optimisation Algorithm (GOA) is applied on challenging problems in multi dimensional optimization. GOA imitates behaviour of grasshopper swarms in order to solve optimization problems. Grasshopper swarm has two tendencies as exploration and exploitation. A search mechanism is needed to adjust the level of exploration and exploitation. During the larval period, grasshoppers can locally move and search food. After the wings have formed, search scale of them increased [24].

III. RESULTS

The purpose of this study is to automatically obtain diseased tissue from MR leg images. For this, the difference between the normal tissue and the diseased tissue is determined by examining the leg tissue images. These differences usually affect the intensity values of the image. Diseased areas in MR leg images appear brighter and more intense than other tissues. However, this process is not as simple as described in practice. When taking a leg image, a large area remains in the image that covers the whole leg or covers other parts of the body. So, there are many misleading factors with high luminance value.
in the image. Also, the images have a lot of noise. These difficulties are misleading for the computer and make it difficult to identify the diseased area. In this study, pre-processing and post-processing are used in addition to an effective segmentation algorithm to overcome the problems mentioned above. Experiments are performed on a computer with Intel i7-5200U 2.4 GHz processor and 8 GB DDR3 RAM.

Segmentation is the process of determining the pixels belonging to different classes in the image. For this, the change in luminance in the image should be examined. Because, diseased tissues cause a change in luminance value in MR images. In this study, the pixel in the image is divided into two classes using Otsu threshold method [25]. The pixel that is higher than the automatically set threshold value is assigned as white and other pixels are assigned as black. White pixels indicate areas of disease. To improve the success of the Otsu threshold method, the algorithm has been optimized. For this purpose; PSO, Differential evaluation, whale optimization and grasshopper optimization algorithms are used. After segmentation, images appear as in Figure 2.

In Figure 2, white pixels are also formed in areas other than diseased areas. The segmentation process is not successful in this case. Therefore, post-processing should be applied to image. The purpose of the post-processing process is to specify all the deficiencies at the end of the segmentation. In this way, the wrongly marked areas are re-moved from image without damaging the correctly marked area. The post-processing approach in this study is to select the largest area. Because the diseased area covers more pixels than the other positive areas. Other positive regions are usually other body parts or misleading masses that remain within the MR image. The images obtained as a result of the experiments are shown in Figure 3. In Figure 3, the white pixel represents diseased tissue. As shown in the figure, the diseased tissues were successfully determined by optimized Otsu thresholding algorithms.

Fig. 2 Segmentation of leg images, a) normal leg image, b) segmented image

Fig. 3 Optimized Otsu segmentation results of leg images, a) normal leg image, b) Ground truth images, c) classical Otsu algorithm, d) PSO-Otsu, e) Differential-Otsu, f) Whale-Otsu, g) Grasshopper-Otsu
Table 1 compares the success of the optimization algorithms used for grasses. Sensitivity, specificity and accuracy parameters are used for the comparison.

<table>
<thead>
<tr>
<th>Algorithm Results</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otsu Method</td>
<td>92.6%</td>
<td>96.1%</td>
<td>94.9%</td>
</tr>
<tr>
<td>PSO-Otsu</td>
<td>94.3%</td>
<td>97%</td>
<td>96.1%</td>
</tr>
<tr>
<td>Differential-Otsu</td>
<td>93.4%</td>
<td>96.6%</td>
<td>95.5%</td>
</tr>
<tr>
<td>Whale-Otsu</td>
<td>95.2%</td>
<td>97.5%</td>
<td>96.7%</td>
</tr>
<tr>
<td>Grasshopper-Otsu</td>
<td>92.76%</td>
<td>96.43%</td>
<td>95.1%</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

In this study, automatically diseased area detection method is presented. MR leg images are used to automatically detect diseased areas in the leg. In the proposed method, important features are determined from the leg images. The most important feature is the change of luminance. These properties are used to separate diseased and normal tissue. But the intense noise ratio of MR images and the technique used during MR imaging make the segmentation process difficult. Therefore, pre-processing and post-processing are added to the segmentation process. In the segmentation process, Otsu thresholding algorithm is optimized using well-known optimization algorithms. Whale optimization algorithm results are better than other methods. But, the results of all methods are close to each other. The proposed method works automatically by eliminating noise and unwanted pixel groups. In future works, segmented images will be classified and information about the diseased will be obtained.

REFERENCES


