Application of AI Techniques in Medical Image Segmentation and Novel Categorization of Available Methods and Tools

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Abstract— **Identification of biological features and the segmentation is done more accurate by applying the artificial intelligence methods. Consequently these methods are so valuable in Medical Image Segmentation. The segmentation methods depend on many factors like disease type and image features. These factors result in remain the segmentation challengeable and lead to increasing the growth of the number of literatures in this field. Categorization of the literatures can help the researchers to understand more easily and rapidly. There are only a few classifications of the papers which none of them considers intelligent methods. In this paper, the applications of AI in medical image segmentation is mentioned first and then a novel categorization is proposed related to the most recent important literatures in four sets based on applying the AI techniques and decreasing human intervention. Available tools are mentioned and classified based on modality and its application finally.**

Index terms— **Categorization of literatures, Medical Image Segmentation, Artificial Intelligence techniques, Medical Tools**

I. INTRODUCTION

Daily growth of medical data volume leads to raise human mistakes in their manual analysis and increase the requests to analyze automatically [1]. Therefore applying some tools to collect, classify, and analyze the medical data automatically is necessary to decrease the human mistakes [2]. Artificial Intelligence (AI) techniques usage in medicine is useful in storage, data retrieval and optimal use of information analysis for decision making in solving problems [3]. Medical imaging issues are so complex owing to high importance of correct diagnosis and treatment of diseases in healthcare systems [1]-[5]. For this reason, algorithms of automatic medical image analysis are used to help in increasing reliability and more accurate understanding of the medical images [6]. AI methods such as digital image processing and also its combinations with others like machine learning, fuzzy logic and pattern recognition are so valuable in visualization and analysis of medical images. Because of intelligent methods can help in precise identification of biological features and accurate analysis at last [5] and [7].

To automate the analysis of medical images using of AI methods, most researchers (e.g. [1], [5], [8] and [9]) have a notation close to the following diagram (see diagram 1):

In diagram1, automatic analysis of medical images needs many image processing techniques and also preprocessing operations like noise removal, image enhancement, edge detection and etc. done in the processing phase. Thus after finishing these preliminary steps, the image is ready for analyzing. Mining Region of Interest (ROI) from the image is done in the segmentation phase by combination of intelligent methods then. Afterward features extraction or maybe features selection is performed to identify and recognize the ROI which may be a tumor, lesion, abnormality and so on.

According to diagram 1, segmentation is crucial as a first step in Medical Image Analysis (MIA) [7]. If it fails, too many errors will appear in the other steps of image analysis such as feature extraction, image measurement, and displaying image [5]. Therefore a proper segmentation method is critical [1]-[9]. In medical applications, segmentation identifies the boundaries of ROIs including the bony structures like distinct bones in the hand, brain parts and tumors [10]-[12], breast calcification [13] and[14], prostate [15], iris [16], abdomen [17], pulmonary fissure [18] and [19] and etc. Some samples of several segmentations are shown in fig. 1 which the segmentation parts are revealed with the specific contours.

Disease type and image features strongly effect on method of segmentation. It leads to dependency on modality and dimension of imaging as well. So there are a lot of literatures in this field which confuse novice researchers. There are a few articles which classified the segmentation methods based on the author's view. For more information about current methods of Medical Image Segmentation (MIS) and also some classification of them you can see [2], [4], [7], [8], [10] and [20]-[28].

The rest of this paper is organized as follows. Section II explains the segmentation of medical images and besides deliberates the application of AI techniques in MIS. Then section III reviews the available classifications of methods as well as it proposes a novel categorization of the most recent important methods based on applying AI techniques and decreasing human intervention. Available Medical softwares are mentioned and classified based on modality, its application and so on in section IV. Finally the paper concludes in section V.
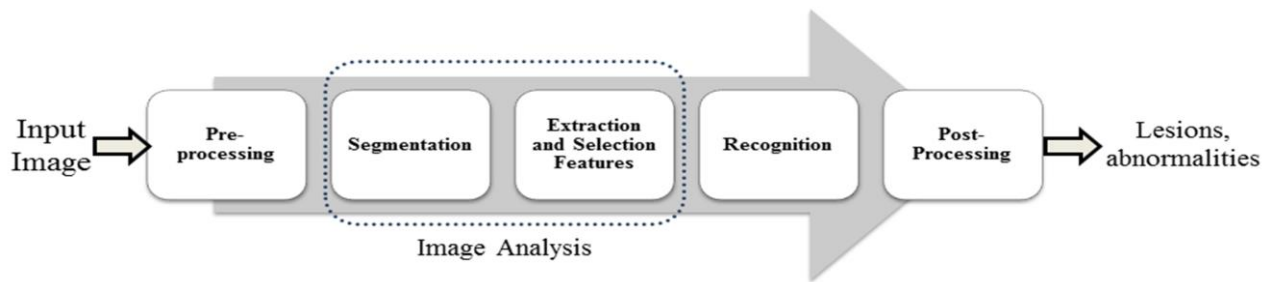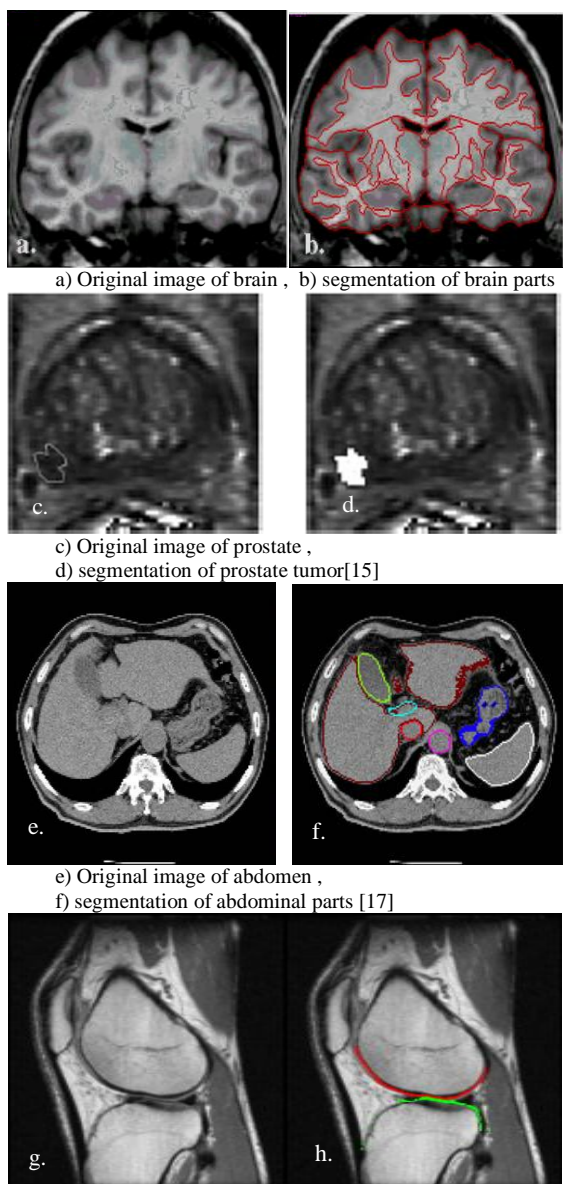
Diagram 1 Automatic Medical Image Segmentation by Intelligent Methods

a) Original image of brain , b) segmentation of brain parts

c) Original image of prostate ,
d) segmentation of prostate tumor[15]

e) Original image of abdomen ,
f) segmentation of abdominal parts [17]

g) Origional image of knee,
h) Segmentation of Femoral & Tibia Cartilage
Fig. 1 Some samples of several segmentations

II. MIS AND THE APPLICATION OF AI TECHNIQUES

Reliable quantitative analysis of medical images, namely the measurement of volumes, needs to describe anatomy structures. This information is obtained by MIA. In MIA, segmentation is required for more concentrations in later steps namely feature extraction, image measurement and ROI representation. Furthermore, obtaining some derminant features of disease or subsequent lesion in MIA, segmentation of the ROI should be done correctly. But this operation is very difficult and is often done by a human operator. Unfortunately this manual segmentation is too time-consuming. So segmentation of many scans is not possible. Additionally the number of images which should be analyzed is growing strongly due to technological advances. Hence, manual segmentation becomes less efficient possibility in clinical operations as well as human interpretation may not be produced suitable. Thus intelligent tools are so essential to segment automatically.

Recent advances in the techniques of AI like image processing, machine learning, fuzzy logic, pattern recognition and knowledge-based analysis result in considering the special needs of MIS to enhancement of diagnosis information by computer. Since desired information about biological objects is related to fundamental features, it's necessary to apply the image processing methods for segmentation and visualization of medical images. Nevertheless realization of radiological interested facts needs special image processing operations. And it's clear that image processing techniques can't provide efficient guidance alone. So the segmentation is performed more accurately by combination of AI methods.

Finally Radiologists can diagnosis cancers, heart disease, infectious diseases, muscular skeletal disorders and analyze them more accurately by using of special and attentive devices for interpretation of the medical images like CT of body facilitated by some AI techniques in medical imaging analysis tools.

III. CATEGORIZATION OF AVAILABLE METHODS AND LITERATURES

The segmentation methods depend on modality and dimension of imaging because of the high dependency on factors like disease type and image features. Likewise, segmentation needs the image interpretation because of its dependency on the considered applications. So these dependencies result in a significant growth of literatures annually [2]. This abundance confuses novice researchers to get an overview. However categorization of the literatures can help the researchers to understand more easily and rapidly. Literature articles about MIS in the journals and conferences proceeding related to medicine, biomedical engineering and computer engineering (e.g. [2], [4], [7], [8], [10], [17], [20]-[28]) can help gaining more significant prior knowledge and therefore a good overview.

Since categorization of the literatures can help the researchers to understand more easily and rapidly, a few classifications of literature has been organized in different categories based on amount of human intervention, application of model and prior knowledge, evaluation and validation of the segmentation method, using local or general data, dimension and modality of imaging, features of disease and so on [4, 30]. None of available classification leads to a crisp partition of them [1]. Some of the categorization is summarized as follows:

In reference [8], the segmentation methods of MRI images have been reviewed until 1995. This article looked over them in aspect of being single or multiple spectral and also being supervised or unsupervised. Some variant methods to segment brain MRI Images have been reviewed in [31]. Several techniques and software tools to support the multispectral and three dimensional medical images have been presented in [21].

Withey [4] and [22] deliberated three generation to classify the literatures. The first generation includes the use of image processing methods and the simplest form of image analysis and also the lowest level of processing. Second generation applies the models, optimization methods and uncertainty models and generally avoids discoveries. Finally, the methods of third generation need to higher level of knowledge like prior information, some rules defined by experts and models of ROI form.

Pan [28] classified the segmentation methods in four groups including interactive thresholding, edge detection, regions split and merge and finally hybrid methods. Thresholding techniques comprise all the pixels with a threshold and identify those pixels within a range of specific areas. Selected threshold is so vital in these methods. Boundary based methods use edge detection techniques like gradient filter to locate the boundaries of the different regions. But these methods are too noise sensitive. Region based techniques claim that the pixels of a region have similar features. A general growing procedure starts from some seed points and comprise each pixel by neighbors. If the merging criterion is satisfied, the pixel will be classified to that class. Naturally, selection of merge criterion is so vital for segmentation success.

Dellepiane [29] classified the literatures based on a tree rooted that partitioned algorithms based on the directorial parameters to their goal. He deliberated density, topology, and geometry as the basis of the main groups.

Accordingly, a novel categorization of the available segmentation methods is proposed in four sets summarized in table 1 and described in the following:

1. **Set 1**: Methods based on *image processing techniques* – i.e. low level processing such as thresholding, edge detection, and region growing and so on (e.g. [26], [28], [31] and [32]).

2. **Set 2**: Using *intelligent methods* in set 1 – The segmentation methods in the set 1 is more accurate by combinations of intelligent method like pattern recognition and machine learning algorithms (i.e., c-means clustering, artificial neural networks, active

contours, level set, hidden markov models and so on) for example [33] and [34]. These methods are trying to be semi-automatic.

3. **Set 3**: Using ability of *Expert system* in set 2 – Considering an expert system by using of the methods in set 2 with the goal of progress toward full automatic segmentation which is using experts knowledge in the form of rules, models [35] and atlases [12], [36].

4. **Set 4**: Using *multispectral and multimodal images* in set 3 which the segmentation method is based on registration. These methods use more several features of multiple modalities comprising with the other sets (e.g. [6], [21], [29], [37]-[39]).

TABLE 1 Novel categorization of MIS methods in four sets with the corresponding literatures

Set 1	Set 2
• Needs low-level processing • Based on image processing techniques such as thresholding, edge detection, and region growing • e.g. [26], [28], [31], [32]	• Combinations of other AI methods with the image processing techniques • Uses pattern recognition and machine learning algorithms in combination of Image processing techniques • e.g. [33], [34]

Set 3	Set 4
• Applying the experts' knowledge in the form of rules, models and atlases with combination of AI methods • e.g. [12], [35], [36]	• Using multispectral and multimodal images in expert system of MIS • Images need to be registerd before segmentation • Co-regrestration segmentation • e.g. [6], [21], [29], [37]-[39]

Not only each set is more complex and accurate but also human intervention would be decreased in comparison than the previous one. Region identification, boundary following, and pixel classification can link the methods in each set to those of previous sets [4] and [5].

There are many efforts to dominate the problems and difficulties in the methods of each set but the result remains already data dependent. Human intervention can be useful to segment semi-automated in methods of set 1 and 2. The methods in set 3 show the promising results which can be comprised with manual segmentation and the progress goes forward to full automated segmentation too.

Most traditional segmentation techniques use the images that represent only one image type, for example, MR or CT. But in set 4, the segmentation method uses multiple images of an organ to have several features by using variant modalities such as CT, MR, PET, ultrasound, or collection of images over time. These features make segmentation more accurate. These methods are called multispectral or multi-modality such as [6], [21], [29], [37]-[39]. There are many intelligent methods applied in this set such as k-means, fuzzy c-means, expectation maximization and adaptive template moderated spatially varying statistical classification etc. and need to image registered properly.

IV. CATEGORIZATION OF AVAILABLE TOOLS

Excerpts of MIS tools are in [2], [21], [23], [40] and [41] and also a large list is maintained in the Internet Analysis Tools Registry [42]. In addition some of available novel tools is declared and categorized in table 2 in aspect of modality, application, dimension and also corresponding body parts. A list of free available software applications used for visualization and analysis of medical modality types such as PET, MRI and CT are cited in [22], [43]-[48]. Some of software tools related to neuroimaging and segmentation of brain tissue and brain abnormalities are in [43], [46], [49] and [50].

V. CONCLUSION

Recent advances in the techniques of AI like image processing, machine learning, fuzzy logic, pattern recognition and knowledge-based analysis result in considering the special needs of MIA to enhancement of diagnosis information by computer. Since desired information about biological objects is related to fundamental features, it's necessary to apply the image processing methods for visualization and analysis of medical images. It's clear that image processing techniques can't provide efficient guidance alone to process the medical image accurate. But realization of radiological interested facts needs to special image processing operations.

Radiologists can diagnosis cancers, heart disease, infectious diseases and muscular skeletal disorders simpler and more accurate by using special and attentive devices for interpretation of the medical images like CT of body facilitated by some AI techniques in medical imaging analysis tools.

In this paper, the segmentation of medical images was explained in detail and the application of AI techniques in MIS was clarified too. Then the available classifications of methods was reviewed as well as a novel categorization of the most recent important methods was proposed based on applying AI techniques and decreasing human intervention. Available medical softwares was mentioned and classified based on the modality, its application, applied segmentation method, dimension of supported images and corresponding part of body.

TABLE 2 Categorization of available tools for different parts of human body

Specification	Modality	Seg. method	Dimension	Body parts	Set
[35] by Royal Philips Electronics	CT MRI	Model-based	3D	cardiac-vascular, artery, all organs	3
Segment [40]	MRI CT PET SPECT	Fast level set	2D 3D	Myocard-ial perfusion cardiova-scular image	3
Reference [41]	CT	Different density masks, anatomic knowledge to differentiate heart	2D	Chest, lung	3
Reference [42]	MRI CT	robust edge-tracking step with an active contour algorithm , level set	3D	wrist	4
MDSTK [51]	Slice formats: DICOM JPEG PNG	Edge detection, thresholding, RG, FCM, Watershed	2D 3D	All	1
ITK-SNAP [52]	MRI	Level set, active contours methods	3D	Brain Liver Kidney	2

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