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Research Directions and Future Trends in Medical Image Segmentation

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Abstract—In the recent years, medical image analysis has turned to be the center of attention for the researchers and practitioners all over the world as it provides high-fidelity and minimally-invasive means for diagnosis, prognosis, therapy and follow-up procedures. Medical image processing techniques in the literature are concentrated vastly on the important processes of filtering, enhancement and object detection, and a variety of methods proposed to improve the image quality for both visual perception and feature detection where the image segmentation is indeed one of the most attractive yet complicated techniques. In this article, a brief updating on computational advances applied to medical image segmentation is provided along with the discussion of some popular methodologies for related medical image processing techniques.

Keywords—Deep Learning; Image Analysis; Image Processing; Image Segmentation; Medical Imaging.

THE traditional medical image processing methods are now being shifted towards hybrid techniques with advanced computational approaches that can be applied to medical images. The medical image data is diverse and complicated where there is a severe driving force to develop next generation technologies to process this data. Machine learning community with its leading technique i.e. deep learning, is getting an integral part to contribute on this challenge of dealing with the large and diverse data. The rapid increase and immense potential of noninvasive medical imaging and data-acquisition techniques have fueled research in mathematical modeling for medical image processing. Of specific interest are robust and automatic methods that can provide repeatability in results as well as high-quality of desired processing. A usual goal in image analysis is the extraction of important detail or features in an image data set for subsequent evaluation, which is typically achieved by segmentation, hence the delineation of the desired object contour [1].

There are also other image processing methodologies that works for filtering noise, contrast enhancement, bias correction, and registration. It has been observed that methods based on partial differential equations are used for image filtering; linear isotropic diffusion is a widely used method for image filtering; and, frequency representation of the image or employ the spatial information of the scene directly for contrast enhancement.

Image segmentation and edge detection are arguably of the most important image-processing tasks. Segmentation is the process of partitioning a digital image into a set of pixels or regions. A segmentation approach should capture perceptually important components or regions. Three problems arise in image segmentation as 1) to provide description of what is perceptually important 2) to specify what a developed segmentation approach does and 3) precise definition of the measures and properties of a resulting segmentation, in order to better understand the method as well as to facilitate the comparison of different approaches. The segmentation approach should run at speeds similar to edge detection or other low-level visual processing techniques in order to be of practical use. Also the visual quality of segmentation is to be maintained at the same time [2]. The methods may be built on different underlying assumptions of how to interpret the information present in an image, and result in making use of various parameters, such as grayscale level, texture, color, or motion. Medical image segmentation is usually performed based on the grayscale values using two different following approaches: 1) by detecting discontinuities or 2) through association by similarity. The latter includes segmenting the image based on the similarity of the intensity between neighboring pixels within a given region, while the former resorts to identifying sudden changes in the grayscale values. Accurate, robust, and automatic segmentation

methods for medical images are keenly sought, in order to facilitate and improve patient data-set analysis and clinical evaluation [3].

The earliest segmentation approaches use fixed thresholds and local measures in computing segmentation. Later the focus was moved towards segmenting the image based on minimum spanning tree (MST) of the graph. For image segmentation, the edge weights in the graph are based on the differences between pixel intensities. The segmentation criterion is to break MST edges with large weights. The inadequacy of simply breaking large edges is that it would result in the high variability region being split into multiple regions. The splitting of such highly variable region is inappropriate. Another class of graph based approaches [4-5] uses the technique which primarily focuses on finding minimum cuts in a graph. The cut criterion is designed in order to minimize the similarity between pixels that are being split. This bias is addressed with the normalized cut criterion. These cut-based approaches to segmentation capture non-local properties of the image, in contrast with the early graph-based approaches. However, they provide only a characterization of each cut rather than of the final segmentation.

The normalized cut criterion [6-8] provides a significant advance over the previous works. However, the normalized cut criterion also yields an NP-hard computational problem. In practice these approximations are still fairly hard to compute, limiting the approach to relatively small images. Later the eigenvector-based approximations [9-10] are related to more standard spectral partitioning approaches on graphs. However, all such approaches are too slow for many practical applications. Also the Eigen vector approach captures computationally important groupings or clusters and not according to human perception. Hence, our focus is moved towards another approach. A graph-based representation of the image developed in [11] uses a segmentation algorithm and found that their approach satisfies global properties. The algorithm runs in time nearly linear in the number of graph edges and is also fast in practice. The specialty of the approach is that it is able to preserve detail in low-variability image regions and ignore detail in high-variability regions. Further improvements in [11] are made by [12] by re-defining the internal difference used to define the property of the components and the threshold function, which is the important factor in determining the size of the components. Deep Learning are set of algorithms used in Machine learning providing and effective and efficient way of analyzing and detecting objects in medical images for automatically detecting and diagnosing medical images. Deep learning methods provide higher level of prediction of objects in medical images and providing critical assessments [13].

Image Segmentation is considered as a critical component of an image analysis and/or pattern recognition system and is still recognized as one of the most challenging tasks in the field of image processing. This is due to the fact that image segmentation is inherently ill-posed. It is considered as NP hard problem. Various algorithms have been proposed for segmenting an image but there is no particular standard on which an image should be segmented. Similarly, the different approaches exist to perform the medical image segmentation, yet no particular approach produces the most efficient segmentation for every medical image. Therefore, the scope of contribution exists in this area and this should motivate us for problem formulation and research in this field. Our goal should be to develop an image segmentation approach that can be broadly useful, just like the other low-level techniques such as edge detection which are utilized in a wide range of computer vision tasks. In order to achieve such broad utility, we believe it is important that a segmentation approach should have the two properties. First is to capture perceptually important groupings or regions, which often reflect global properties of the image. And second is to run the segmentation approach at the speeds similar to edge detection or other low level process. A researcher working in this field will always try to develop an approach for image segmentation considering these two factors [14].

With regards,

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