A Review of the Medical Image Segmentation Algorithms

J. E. Anusha Linda Kostka

Abstract The discovery of X-ray in 1895 initiated the era of medical imaging diagnostics. Since then, medical imaging systems have realized unprecedented advancements. These systems have also turned out to be invaluable tools in the practice of diagnostic medicine. However, despite the significant development in medical imaging technologies, processing medical images still pose a substantial challenge especially when it comes to image segmentation. That problem is gradually being alleviated by the implementation of digital medical image processing, especially in the diagnosis and treatment of brain tumors. But the capability of most of the contemporary image delineating algorithms remains limited. Therefore, there is a need to come up with the new medical image segmentation programs to fully utilize the power of digital image processing. In light that, this article reviews some of the contemporary algorithmic protocols for brain tumor delineation systems and how effective they are.

Keywords Algorithm · Brain tumor · Digital imaging processing · Image segmentation

1 Introduction

Image processing is "the manipulation and analysis of information contained in images" (Maintz 2005, p. 10). On the other hand, the digital medical image processing means the delivery of digital images processing for medicine [1]. Image processing includes various core stages. These are the image creation, visualization, analysis, management, and enhancement phases. At the creation stage, an image is captured and then rendered into a digital image matrix by the use of suitable sensors [1, 2]. At visualization leg, the model formed is manipulated to output an optimized image.

During the analysis point, the image is quantitatively measured and abstractedly interpreted [1]. This stage requires prior knowledge and a precise set of algorithms to

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ensure that whatever the image represents is discerned correctly [1]. The management part of image processing involves efficient storage, communication, and transmission, archiving, and retrieval of the image [1]. The last phase, image enhancement, is a low-level processing step. Unlike analysis, it requires little knowledge and can either be manual or automatic [1].

2 The Challenges of Image Segmentation

The most significant problems doctors encounter in medical image processing are low quality, the varying nature of image captured even with standardized image-creating protocols, problematic delineation of objects, and complicated algorithms [1]. As a result of these challenges, image segmentation is one of the most crucial parts of image processing since it ensures the accuracy of an interpretation and ultimately that of diagnosis. Segmentation is a technique for separating objects from the background [3]. This process is one of the most challenging procedures in medical imaging processing. The reason for this is because most of the modalities used for capturing medical images are harmful to the body. Consequently, they are required to be used in small doses and at lower energy [1]. Therefore, the outputs usually have poor signal-to-noise ratio. Since manual segmentation needs a trained radiologist and takes a lot of time and energy, [3] argue that it is crucial to automate this process to expedite the process and improve on the accuracy and dependability of diagnosis.

3 Proposed Segmentation Algorithms: Sobel Operator, Dependent Thresholding, and Close-Contour Methods

With the aim to create a perfect algorithm for brain tumor segmentation, Aslam et al. [3] propose a modified model combining Sobel operator and automatic dependent thresholding methods for the extraction of tumor edges with the aim of extending to object segmentation (p. 431). Then, closed-contour is applied on those edges to locate closed areas of an image. Finally, the tumor is extracted from the MRI image. The projected algorithm has four stages. These are (1) looking for gradient image by Sobel operator, (2) calculating image-dependent threshold repeatedly, (3) use closed-contour algorithm, and (4) separating the object based on the pixel concentration inside the closed contour [3]. Figures 1 and 2 denote the modified algorithm compared to the conventional one.
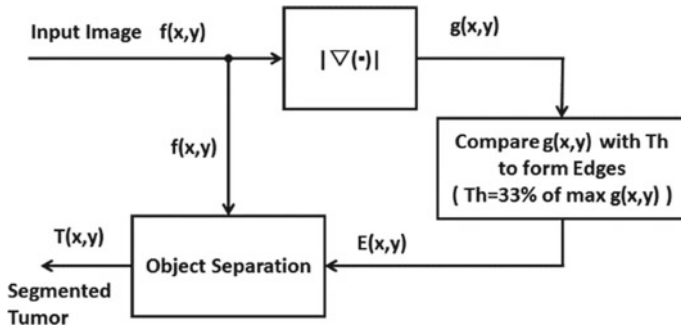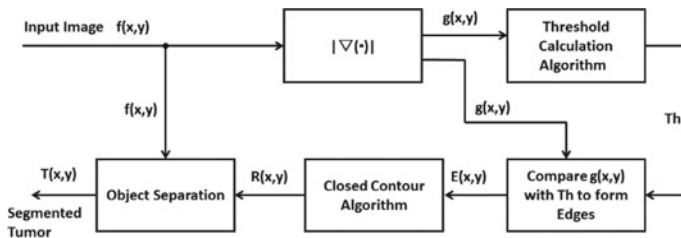
Fig. 1 Conventional algorithm

Fig. 2 Proposed algorithm

4   New Triple Modality: MRI-Photoacoustic-Raman-Nanoparticle

Kircher et al. [4] propose the use of a novel triple protocol that combines magnetic resonance imaging (MRI), photoacoustic imaging, surface-enhanced Raman scattering (SERS), and injections of nanoparticles (MPRs) to the tumor to map its margins accurately (p. 3) that allows for the complete removal of a tumor during surgery which is essential for the treatment of tumors [4]. The results of an experiment conducted on mouse glioblastoma models indicate that this technique performance is superior to most of the usual methods in use today. The triple-modality method depends on injecting MPRs, which have higher permeability properties and are only absorbed by the tumor. The MPRs are also retained for a more extended period by the malignant cells [4]. Once the three modalities are applied, the entire tumor location is mapped in more precise details. Also, given that the injected MPR stays for a protracted period in the tumor, both the pre-operational evaluations and the operational processes since the radiologist and neurosurgeon see the same probe preoperatively and during surgery. The photoacoustic imaging allows for high spatial resolution, three-dimensional imaging while the Raman imaging offers high sensitivity and high-resolution surface imaging. The Raman imaging properties also allow for post-operation analysis, which provides for explicit confirmation of margins [4].
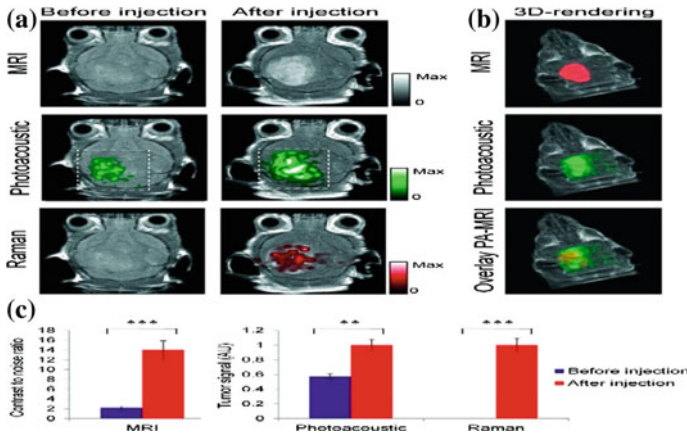
Fig. 3 Kircher et al.'s [4] representation of pre- and post-triple-modality trials

The tests' definitive conclusions are a consequence of the high longitudinal relativity of MPRs that is the highest of any nanoparticle ever reported [4]. The photoacoustic imaging allows the imaging of deeper tissues with high three-dimensional resolution. With the MPR's excellent optical absorbance and the 3D capability of the photoacoustic, the process allows even for the tumor hidden behind normal brain cells to be detected [4]. Raman imaging, which has super sensitivity, is then applied to map the tiniest of the tumor masses [4]. The property of the MPRs permits repeated imaging without the need for more injections [4]. Overall, the triple-modality method of delineating brain tumor tissues improves the localization of the tumor and significantly improves the signal-to-noise ratio as shown in Fig. 3.

5 Conclusion

The technology for medical imaging has taken big strides since the invention of the X-ray in 1895. Despite the unparalleled technological advancement in the photography field, medical imaging still suffers from many shortcomings. One of the biggest issues that hinders medical imaging is low-quality images. Since most of the modalities used for imaging in the healthcare sphere are harmful to the body, they are applied in low doses and operated at low-energy levels. As a result, medical images are afflicted by poor signal-to-noise ratios that make it difficult for medical professional to evaluate a diagnosis, especially when it comes to segmentation of brain tumor. But recent studies propose new models and protocols for image alienation that aims at improving this process. One of the proposed processes involves the combination of Sobel operator, automatic dependent thresholding, and close-contour methods with the final stage being the extraction of the tumor image from the MRI. The other method includes the use of a triple-modality system that utilizes magnetic resonance imaging (MRI),

photoacoustic imaging, surface-enhanced Raman scattering (SERS), and injections of nanoparticles (MPRs) to the tumor to enhance the mapping of the tumor margins accurately. Both of these proposed protocols have shown great potential as shown by the sample images above.

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