AN OVERVIEW OF CHALLENGES IN MEDICAL IMAGE PROCESSING

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ABSTRACT

Computers and various imaging technologies effectively enhanced the diagnostic procedures of medical imaging, where various medical images enhance the early diagnosis, characterizing and discriminating of different health problems, which lead to efficient healthcare services and treatments. Digital image processing and medical images analysis can significantly support medical diagnosis by providing the necessary tools for automatic detection, extracting significant information and accurate measurement of visible abnormalities. However, there are many challenges related to medical images as well as challenges that arise during the various stages of image processing. This paper provides an overview of different challenges related to medical images and medical image processing. The most prominent and significant challenges are identified and introduced not to discourage the interested researchers in this field of image processing, but to fill the gap of missing a comprehensive overview on these challenges.

CCS CONCEPTS

• **Image processing**; • **medical images**; • **medical images challenges**;

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1 INTRODUCTION

Image processing is widely used in many applications such as multimedia, biomedical imaging, biometrics, remote sensing, forensic studies, textiles, material science, defense surveillance, document processing, and medical imaging and more (Acharya and Ray, 2005). Attention to digital image processing stems from two main areas: improving graphic information for appropriate decision-making; and processing, storing and transmitting image data. A digital image is composed of finite elements called image pixels. Each element has a specific location and value.). Images are presented in 2-D as well as in 3-D domain. Each element in the 2-D domain is called pixel, and it is called voxel in 3-D domain. Sometimes 3-D images are represented as a successive series of 2-D slices in order to reduce computational complexity and the required memory (Sharma and Aggarwal, 2010). Digital image processing is the processing of digital images by means of a digital computer. The computerized processes include (Gonzalez and Woods, 2008):

- Low-level processes: They include noise reduction, contrast enhancement, image compression and image sharpening processes.
- Mid-level processes: They include image segmentation, feature extraction and objects classification.
- Higher-level processes: They include perceiving the classified objects to reach out the correct decision about the goal of image processing.

However, researchers face several challenges in image processing of medical images. Some of these challenges are inherited in the medical images and others are related to diseases characteristics, and the techniques and methods of image processing. This paper provides an overview of some of the main challenges of the medical images and their processing. The rest of the paper is organized as

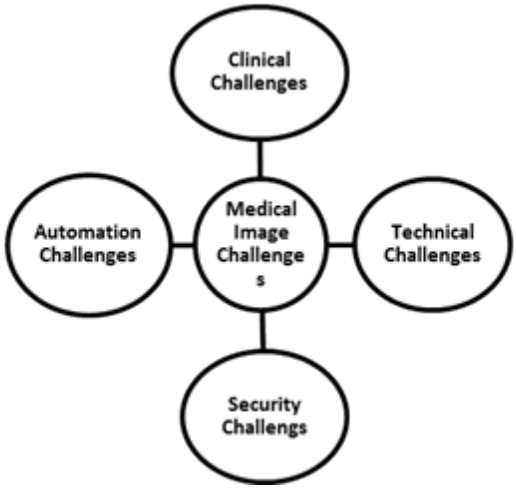

Figure 1: Medical Image challenges

follows. Section 2 introduces the medical image concept, types, and importance. Section 3 presents several challenges of medical images. Section 4 demonstrates many challenges arise during various stages of image processing, while conclusion is presented in section 5.

2 MEDICAL IMAGES

Medical images provide visualization of parts of human body, tissues, or organs, for medical check, diseases detection, monitoring and treatment (Hemamalini and Prakash, 2016). Medical image analysis comprises tissues structure and function anatomy. It encompasses segmentation of image, extraction of feature, classification, image matching/registration and anatomical measurement and images physiological parameters (Mitra and Shankar, 2015). Analysis of medical image is focused on deriving knowledge from images obtained from imaging devices such as X-Ray, CT scan and MRI (Manojbhai and Rajamenakshi, 2016). Analysis of MRI, CT scan X rays Images enable and contribute to detect and solve problems of dangerous and complex disease like lung and breast cancer, brain tumors, etc. Image processing assists doctors to diagnose and analyze such diseases (Hemamalini and Prakash, 2016). Management of medical image database assists to share patient data among medical institutes and provide information on health and diagnosis (Chitla and Chandra Mohan, 2014). The medical image processing field and the applications in computer assisted diagnoses and therapy has great importance in modern medicine. The field is deemed as an engineering discipline independent from medical problems and clinical practices (Horsch and Thurmayr, 2003). The basic motive of medical image processing is to extract clinical knowledge or information from medical images (Mishra et al., 2014).

3 MEDICAL IMAGES CHALLENGES

The medical imaging role has extended from visualization and disease diagnosis to be a tool for simulation and treatment planning, extracting information on anatomic structures, and for tracking the disease progress (McInerney and Terzopoulos, 1996). However, they suffer from different challenges, which are demonstrated in Figure 1.

3.1 Clinical Challenges

Digital image processing and analysis has a critical role in clinical practice. Several studies indicated that computerized medical systems can enforce medical diagnosis by enabling automatic detection, recognition of useful information, disease evolution monitoring and accurate measurement of visible abnormalities (Iakovidis, 2015). For example, clinical diagnosis is the basic modality for identifying cancer; but visual diagnosis alone is not sufficient to define tumor depth. Imaging allows lesion mapping, which could assist surgeon to determine tumor extent that can help to reduce the next surgeries stages (Bard, 2017). Expert radiologists collect information from a first glance at an image based on their experience and the information that could be extracted from the image. Searching images for significant clinical findings is a common task for radiologists. However, this task is difficult and mistakes may be made although error is very costly (Drew et al., 2013). Automation helps to reduce error margin even the diagnostics accuracy is not always acceptable and includes some errors due to imaging devices technical errors (Hoshyar et al., 2014).

3.2 Technical Challenges

The rapid development of technology and use of different imaging modalities led to emerge more challenges such as how to get high quality images, how to get high quality information from processing and analyzing images, which contribute for disease diagnoses and treatment (Zhu, 2003). Medical images contain inconsistent conditions; such as they acquired under various illumination conditions and from different distances. Moreover, the images may have poor resolution, which makes the lesion detection and diagnosis difficult when it is small. Furthermore, clinical images may contain hair, reflections and shadows, which may impede the lesions discrimination and analysis (Oliveira et al., 2016). Moreover, the images contain variances in brightness and lighting conditions and

noises such as presence of hair etc. (Chakravorty et al., 2016) which makes the diagnosis process of disease difficult. For example CT images may contain noise, blur and low contrast due to X-ray nature and low radiation dose, which is currently used to mitigate the dangerous radiation effects. These issues affect the medical images quality and diagnosis of diseases (Al-Ameen and Sulong, 2016).

3.3 Automation Challenges

Currently, the medical image data amount grew rapidly due to the development of medical image acquisition devices. Since most imaging modalities became digital, with continually increasing resolution, medical image processing has to face the challenges of big data (Scholl et al., 2011). Therefore, it is challengeable to manage, analyze, and store theses data. Automation helps to mitigate these challenges; however, automatic analysis of medical images requires many image processing techniques such as feature extraction and segmentation and also pre-processing operations like noise removal, image enhancement, edge detection etc (Roy and Phadikar, 2014). Computer-assisted diagnosis technologies utilize automated systems, methods, and techniques to analyze and extract data to provide high accuracy diagnosis without subjective human interpretation bias. The computer-aided diagnosis aims (Sharma and Aggarwal, 2010):

- To automate the process to handle many cases with the same accuracy regardless overwork or data overload.
- To provide fast and perfect results.
- To support communication among health institutions over wide area using information technology.

However, automation of medical image processing techniques is not easy task due to the complex nature of the medical images.

3.4 Security Challenges

Medical images are the confidential patients' data. They contain highly valuable information essential for diseases diagnosis and treatment. Therefore, it is quite important to secure their storage, processing, analysis, and transmission without violating the legal and ethical issues regarding health information privacy (Al-Dmour and Al-Ani, 2016). These challenges are emerged due to multimedia and communication technologies development (Arsalan et al., 2012), which make tampering, destruction or copying of digital images a simple process (Barani et al., 2015). Therefore, attaining high security for medical images is very challenging issue, especially with increasing risks via the Internet. This requires achieving three compulsory features: availability, reliability and confidentiality. The medical image should not subject to any illegal alteration or modification since any degradation to images quality will affect diseases diagnosis (Das and Kundu, 2013).

Several methods are used to attain effective security for medical images such as cryptography, steganography, and watermarking. Encryption is an effective method to secure medical images. However, many encryption methods such as data encryption standard, advanced encryption standard and international data encryption algorithm are not suitable for digital images that characterized by high correlation and redundancy of pixels (Zhang et al., 2015). Moreover, these methods need large overhead, and they are expensive for real-time applications (Tabashet al., 2013). Steganography methods suffer from significant challenges related to achieve the balance among visual quality, imperceptibility, the payload. They suffer from another challenge related to their ability to resist different attacks (Wang et al., 2010). Watermarking is used for hiding medical data, integrity verification and for authentication; however the watermarking embedding may cause image distortion which is not acceptable for some images such as military and medical images (Zhang et al., 2013; Barani et al., 2015). Same as steganography, watermarking the balance among robustness, imperceptibility, and capacity of embedded data. Furthermore, watermark should be sensitive to any images modifications and should resist all attacks types.

4 MEDICAL IMAGE PROCESSING CHALLENGES

Computers and various imaging technologies effectively enhanced the diagnostic procedures of medical imaging, where various medical images enhance early diagnosis, characterizing and discriminating of different health problems, which lead to efficient healthcare services and treatments. However, many challenges arise during the image processing various.

4.1 Preprocessing Challenges

Preprocessing of image is the preliminary step for enhancing the images quality. It includes medical image enhancement and restoration. However, there are many challenges related to these issues. To mitigate these challenges, several techniques and methods are utilized. For denoising, several methods are used such as, wavelet thresholding, Gaussian smoothing, anisotropic filtering, and more. However, they certainly blur some details or remove some of the image important details and may produce an unrealistic contrast, which increases the difficulty of disease identification. Also, for deblurring, many used methods such as Richardson-Lucy algorithm, Wiener filter regularized filter inverse filter, and more may cause noise amplification, boundary artifacts, and high calculations. In the same way, the methods for contrast enhancement such as normalization, histogram equalization, low and high pass, contrast stretching, and more may cause abnormal brightness, unnatural appearance and noise amplification (Al-Ameen and Sulong, 2016).

4.2 Segmentation Challenges

Medical images segmentation is a significant step for providing assistance to medical experts in detecting diseases. It helps to find the lesion location, and estimate the disease probability (Afifi et al., 2015). Segmentation can assist to conduct further analysis, quantification or simulation for organs, tumors, and other objects (Läthén, 2010). Segmentation is an earlier and significant step to image analysis; however, it is difficult to conduct and automat accurately (Thirumaran and Shylaja, 2015). Image segmentation is influenced by several factors, such as images homogeneity, image continuity spatial characteristics; image and texture content (Kannan et al., 2015). The segmentation techniques outcome is influenced by several artifacts during image processing such as noise artifact, nonsharp edges, motion and, intensity inhomogeneity (Sharma and Aggarwal, 2010). Segmentation removes redundant information and facilitates objects visibility (Smistad, 2015). Moreover, there is

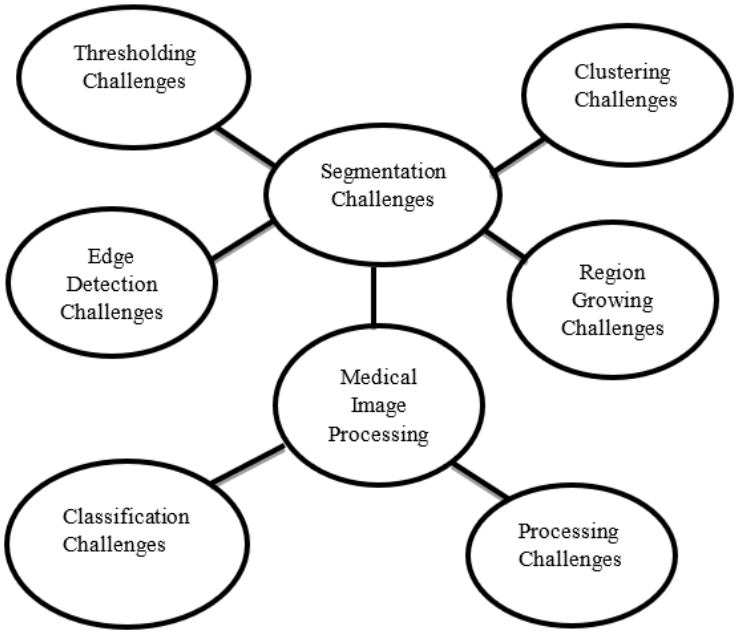

Figure 2: Image Processing Challenges

no optimal technique for image segmentation, because each image has its own diverse type. On the other hand, it is hard task to find a segmentation method for a certain image type (Khan, 2013). Generally, it is acknowledged that there is no broad strategy for solving all segmentation problems (Läthén, 2010). Segmentation can be classified into the following:

4.2.1 Region Growing Challenges. Region based segmentation is simple compared with other methods and also noise resilient (Khan, 2013). The region growing technique groups the pixels into larger regions based on similarity criteria relating to their intensity, color or object. However, similarity criteria alone are not an effective for segmentation and it is necessary to consider the adjacency spatial relationships between pixels (Solomon and Breckon, 2011). This technique of segmentation doesn't considered robust (Thirumaran and Shylaja, 2015), because its performance depends on regions selection and if these regions are clearly and accurately defined. Moreover, there is a possibility of image over or under-segmentation (Wanjari et al., 2015). Over-segmentation occurs if a specific object is decomposed into many segments or segments parts, while under-segmentation occurs if obtained segments are integrated from several objects parts. The significant problem with medical images segmentation is the simultaneous occurring of both over and under-segmentation (Deserno, 2011).

4.2.2 Thresholding Challenges. Thresholding is one of the easiest and most commonly used techniques for image segmentation because of its simplicity, robustness, and accuracy (Sharma et al., 2015). It identifies image objects based on their intensity values. It is useful to discriminate background from the foreground (Mandal and Baruah, 2013). In this technique, a correct threshold values should be applied to obtain correct segmentation results. However, threshold selection is a difficult task (Sharma and Aggarwal, 2010), and wrong threshold leads to destroy the object contour (Afifi et al., 2015). On other hand, this technique suffers from its sensitivity to accidental and uncontrolled illumination variations; and its inefficiency when the edges are smooth, and affected by noise. Moreover, in this technique, the spatial relationships between pixels are not considered (Läthén, 2010; Solomon and Breckon, 2011).

4.2.3 Edge Detection Challenges. The edge detection technique is the most popular technique. It is based on detection of edges (boundaries) that split up regions by coding the discontinuities in color, gray level, etc. However; its performance is affected by noise, and the presence of fake and weak edges in the image which affect the segmentation results. Moreover, and for complete segmentation, these techniques should be coupled with region-based techniques (Sharma and Aggarwal, 2010). Various edge detection algorithms have been applied to extract boundaries between different disease tissues; however such algorithms are sensitive to artifacts and noise (Udomhunsakul and Wongsita, 2004; Thirumaran and Shylaja, 2015).

4.2.4 Clustering Challenges. Clustering techniques are based on grouping observed objects into clusters according to a similarity or distance measure (Omar, et al., 2013). In image processing, clustering technique splits the image into clusters of similar characteristics pixels using a membership functions (Solomon and Breckon, 2011).

However, the determination of the membership is not easy task (Kaur and Kaur, 2014). Clustering techniques are characterized by computational cost due to use distance calculation metrics such as Euclidean and Mahalanobis distances (Deserno, 2011). Clustering techniques may not provide optimal results; moreover, there is no perfect clustering algorithm for a specific application (Sharma and Aggarwal, 2010).

5 CLASSIFICATION CHALLENGES

The classification aims to detect and categorize objects (cancer, lesion, and tumor) in a medical image into classes (Zahradnikova et al., 2015). Image classification is the classifying pixels process into determinate set of distinct classes based on their data values (Thakur and Maheshwari, 2017). High classification rate can be achieved by extracting the significant object features. The efficiency of features extraction depends on the efficiency of the feature extraction techniques (Jebur et al., 2015). Medical images feature extraction has a significant role in increasing segmentation quality and enhancing classification process. The classification rate depends on the extracted features, dataset, and the efficiency of the classification techniques. Several challenges are identified for feature extraction such as how to select best features for class discrimination, which features should be extracted, what is the best technique for feature excretion, and more. For the dataset, several challenges arise such as the suitable dataset size and training samples, and data imbalance problem (Sufficient representative images in the dataset for all classes) (Zhang et al., 2017). For the classification, various methods and techniques have been utilized. However, categorizing objects is a difficult task and need more researches (Zahradnikova et al., 2015). Moreover, classification techniques or methods have pros and cons and they vary in their performance. Generally, false alarms, and missing fatal diseases are not accepted, thus, developing techniques for medical image processing and analysis needs comprehensive validation studies to guarantee the results usability in practice (Läthén, 2010).

6 CONCLUSION

Errors or uncertainties in image processing cannot be avoided; some of them are common in image processing such as those related to image acquisition (limited resolution, distortion). Others are related to the interpreting the images by human, as well as those related to limited capability of the used techniques and methods (Jannin et al., 2006). Researchers should identify these issues clearly and accurately, and provide the required solution or at least mitigate them in order to provide effective medical image processing, which helps in diseases diagnosis and treatment. Medical images analysis by human expert is relatively limited due to images complexity; wide disparities exist across diverse experts, and fatigue. Automated tools for image acquisition, diagnosis, enhancement and interpretation based on machine learning algorithms provide accurate and efficient solutions for improving medical image processing. Therefore, generic technologies for image analysis that can effectively be adapted for a certain clinical task are required (Weese and Lorenz, 2016).

REFERENCES

[1] Mitra, S., & Shankar, B. U. "Medical image analysis for cancer management in natural computing framework". Information Sciences., vol. 306, pp. 111-13, 2015.

[2] Hemamalini, G. E., Prakash, J. "medical image analysis of image segmentation and registration techniques". International Journal of Engineering and Technology, pp.160805205. 2016.

[3] Chitla, A., & Chandra Mohan, M. Authenticating "Medical Images With Lossless Digital Watermarking",International Journal Of Multidisciplinary And Current Research, 2014.

[4] Arsalan, M., Malik, S. A., & Khan, A. "Intelligent reversible watermarking in integer wavelet domain for medical images". Journal of Systems and Software, vol.85(4), pp.883-894, 2012.

[5] Barani, M. J., Valandar, M. Y., & Ayubi, P.. "A secure watermark embedding approach based on chaotic map for image tamper detection". In Information and Knowledge Technology (IKT),7th Conference on (pp. 1-5). IEEE, 2015.

[6] Das, S., & Kundu, M. K. "Effective management of medical information through ROI-lossless fragile image watermarking technique. Computer methods and programs in biomedicine", vol.111(3), pp.662-675, 2013.

[7] Tabash, F. K., Rafiq, M. Q., & Izharrudin, M. "Image encryption algorithm based on chaotic map'. International Journal of Computer Applications, vol.64 , 2013.

[8] Wang, J., Sun, Y., Xu, H., Chen, K., Kim, H. J., & Joo, S. H. "An improved section-wise exploiting modification direction method. Signal Processing", vol.90(11), pp. 2954-2964, 2010.

[9] Solomon, C., & Breckon, T. Fundamentals of Digital Image Processing: A practical approach with examples in Matlab. John Wiley & Sons. 2011.

[10] Mandal, A. K., & Baruah, D. K. "Image Segmentation Using Local Thresholding And Ycbcr Color Space". Journal of Engineering Research and Applications, Vol. 3 (6), pp. 511-514, 2013.

[11] Udomhunsakul, S., & Wongsita, P. (2004, December). "Feature extraction in medical MRI images". In Cybernetics and Intelligent Systems, IEEE Conference on (Vol. 1, pp. 340-344) IEEE, 2004

[12] Afifi, A., Ghoniemy, S., Zanaty, E. A., & El-Zoghdy, S. F. New region growing based on thresholding technique applied to MRI data. International Journal of Computer Network and Information Security, vol 7(7), 61. 2015.

[13] Al-Ameen, Z., & Sulong, G. "Prevalent Degradations and Processing Challenges of Computed Tomography Medical Images": A Compendious Analysis. International Journal of Grid and Distributed Computing, vol.9(10), pp.107-118, 2016.

[14] Deserno, T. M. Fundamentals of biomedical image processing. In Biomedical Image Processing Springer Berlin Heidelberg. pp. 1-51,2010.

[15] Horsch, A., & Thurmayr, R. "How to identify and assess tasks and challenges of medical image processing". In Proceedings of the Medical Informatics Europe Conference (MIE 2003), St. Malo, France Vol. 2815. 2003.

[16] Jannin, P., Krupinski, E., & Warfield, S. K. "Validation in medical image processing. IEEE Transactions on Medical Imaging", vol.25(11), pp.1405-9, 2006.

[17] Läthén, G. "Segmentation methods for medical image analysis". Linköping studies in science and technology Thesis, vol.2(2), pp.1403-1408. 2010.

[18] Mishra, A., Rai, A., & Yadav, A. "Medical image processing: A challenging analysis. International Journal of Bio-Science and Bio-Technology", vol.6(2), pp.187-194, 2014.

[19] Omar, S., Ngadi, A., & Jebur, H. H. "Machine learning techniques for anomaly detection: an overview".International Journal of Computer Applications, vol.79(2), (2013).

[20] Scholl, I., Aach, T., Deserno, T. M., & Kuhlen, T."Challenges of medical image processing. Computer science-Research and development", vol.26(1), pp.5-13, 2011.

[21] Sharma, A., Chaturvedi, R., & Chaturvedi, U. 'Recent trends and techniques in image segmentation using practical swarm–Optimization–A survey". International Journal of Scientific and Research Publications, vol.5(6), 2015.

[22] Thirumaran, J. Shylaja, S. "Medical Image Processing – An Introduction". International Journal of Science and Research, vol.4 (11), 2015.

[23] Wanjari, M. T., Kalaskar, K. D. , Dhore, M. P. "Document Image Segmentation using Region Based Methods". International Journal of Computing Science and Information Technology, Vol.3(3) , 2015.

[24] Zhang, L. B., Zhu, Z. L., Yang, B. Q., Liu, W. Y., Zhu, H. F., & Zou, M. Y. "Medical image encryption and compression scheme using compressive sensing and pixel swapping based permutation approach". Mathematical Problems in Engineering, 2015.

[25] Zhu, H. "Medical image processing overview. University of Calgary", 2003.

[26] McInerney, T., & Terzopoulos, D. "Deformable models in medical image analysis: a survey". Medical image analysis, vol.1(2), pp. 91-108, 1996.

[27] Khan, Khan, M. J., Bhattacharyya, A., & Alam, M. "design issues and challenges of reliable and secure transmission of medical images", 2014.

[28] Smistad, E. Medical Image Segmentation for Improved Surgical Navigation. PhD thesis. Norwegian University of Science and Technology Norwegian University of Science and Technology. 2015.

[29] Acharya, T., & Ray, A. K. "Image processing: principles and applications". John Wiley & Sons, 2005.

[30] Gonzalez, R. C., & Woods, R. E. "Digita Image processing". 3rd ed. Pearson Prentice Hall, 2008.

[31] Solomon, C., & Breckon, T. Fundamentals of Digital Image Processing: A practical approach with examples in Matlab. John Wiley & Sons, 2011.
[32] Manojbhai, D. D., & Rajamenakshi, R. "Large Scale Image feature extraction from medical image analysis" International journal of advanced engineering and research, 2016.
[33] Al-Dmour, H., & Al-Ani, A. "Quality optimized medical image information hiding algorithm that employs edge detection and data coding". Computer methods and programs in biomedicine, vol. 127, pp. 24-43, 2016.
[34] Drew, T., Evans, K., Võ, M. L. H., Jacobson, F. L., & Wolfe, J. M. "Informatics in radiology: what can you see in a single glance and how might this guide visual search in medical images?". Radiographics, vol.33(1), pp.263-274, 2013.
[35] Hoshyar, A. N., Al-Jumaily, A., & Hoshyar, A. N. "The Beneficial Techniques in Preprocessing Step of Skin Cancer Detection System Comparing" .Procedia Computer Science, vol. 42, pp.25-31, 2014
[36] Oliveira, R. B., Marranghello, N., Pereira, A. S., & Tavares, J. M. R. "A computational approach for detecting pigmented skin lesions in macroscopic images". Expert Systems with Applications, vol.61, pp.53-63, 2016.
[37] Chakravorty, R., Liang, S., Abedini, M., & Garnavi, R. "Dermatologist-like feature extraction from skin lesion for improved asymmetry classification in PH 2 database". In Engineering in Medicine and Biology Society (EMBC), IEEE 38th Annual International Conference of the , pp. 3855-3858, 2016.
[38] Roy, K. K., & Phadikar, A. "Automated Medical Image Segmentation: A Survey". In Proc. of Int. Conf. on Computing, Communication & Manufacturing, 2014.
[39] Hemamalini, N., & Aggarwal, L. M. "Automated medical image segmentation techniques". Journal of medical physics/Association of Medical Physicists of India, vol.35 (1), pp.3, 2010.
[40] Kaur, D., & Kaur, Y. "Various Image Segmentation Techniques: A Review". International Journal of Computer Science and Mobile Computing, 3(5), 809-814, 2014.
[41] Bard, R. L. "High-Frequency Ultrasound Examination in the Diagnosis of Skin Cancer". Dermatologic Clinics, 2017.
[42] Zhang, J., Zhang, Q., & Lv, H. "A novel image tamper localization and recovery algorithm based on watermarking technology". Optik-International Journal for Light and Electron Optics, vol.124(23), pp.6367-6371, 2013.
[43] Mahmood, Omar Abdulkareem, and Yousif I. Hammadi. "Enhanced 5G contender based flat top weighted window communication systems." Bulletin of Electrical Engineering and Informatics 11.1 (2022): 364-371.