A Comprehensive Analysis of Medical Image Fusion Techniques: A Detailed Review

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Abstract: Image fusion involves merging a collection of images of the same scene to create a single composite image. Its purpose is to generate a more visually appealing image or to extract additional valuable information from it. The main aim of image fusion is to produce a new image that contains high-quality data, which cannot be obtained through other means. This process combines multisensor, multiview, and multitemporal data to create a single, comprehensive image. Image fusion techniques have been applied in various fields, including remote sensing, astronomy, and medical imaging. In medical imaging, image fusion has been particularly useful for simultaneously evaluating CT, MRI, and PET images to find what type of disease or its effect. In this paper, we present a novel literature review on image fusion techniques applied to medical images. Our findings suggest that image fusion can greatly improve the clinical reliability of disease diagnosis and analysis, and we anticipate strong growth in this field in the near future.

1 INTRODUCTION

Image fusion is a progression method of merging a set of images of the same scene into one composite image. Fusioning is done in order to get an enhanced image or to enhance some useful information from it. Image fusion in medical field has seen significant growth several years and it incorporates a broad range of techniques in the field of image fusioning.

The fusion process aims to address medical conditions or diseases by analyzing images of the human body, organs, and cells. With advancements in computer-aided imaging techniques, this process helps medical experts make more informed decisions in a shorter amount of time. By using fusion methods on multi-sensor and multi-source images, a wider range of features can be used for medical analysis which is leading to more precise information processing and the ability to uncover details that may be invisible to the human eye. Additional Information is obtained from fused images, which lead to locate abnormalities, more accurately. Image filters are indeed a fundamental concept in image processing, and they are used to enhance, manipulate, or extract information from images. There are various types of image filters, such as spatial filters, frequency filters, and edge detection filters, each serving a specific purpose in image processing. In spatial domain filtering, a filter is applied directly to the pixels of the

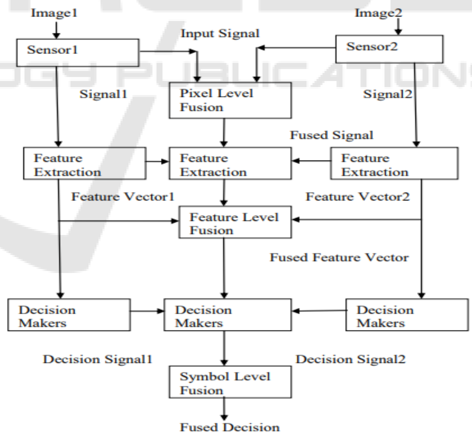

Figure 1: Information fusion system at all three levels of processing.

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image, and it can be utilized for smooth or sharpen images, remove noise or enhance specific features. Spatial filters are often used for real-time image processing applications, such as video or camera feeds, as they are faster than frequency domain filters. Image processing has various applications, as you have mentioned. It is used in computer vision tasks, such as object recognition, face detection, and motion tracking. In security, image processing can be used for surveillance systems and access control. It is also used in entertainment and gaming industries, for creating special effects or developing interactive games. One of the most important uses of image processing is in medical imaging. Medical images, such as X-rays, CT scans, or MRI, are used to diagnose and treat various diseases and conditions. Image processing can help improve the accuracy of medical image analysis, by enhancing the contrast between different tissues, segmenting specific regions of interest, or detecting abnormalities.

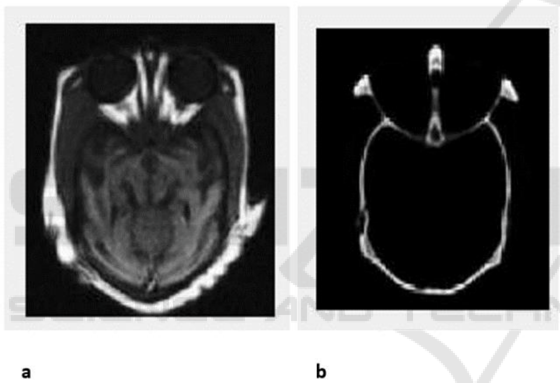

Figure 2: (a) MRI Image used as source image (b) CT Image.

Deep learning models can also be trained on huge set of database of medical images, to automatically detect and diagnose certain conditions, such as cancer or fractures. This can greatly improve the speed and accuracy of medical diagnosis, and help doctors make more informed decisions about patient care.

Medical Image Fusion.

Medical image fusion comprises of processing and grouping of multiple images acquired from single or multiple imaging modalities. The key aim of this process are to increase the quality of medical images, decrease randomness and redundancy, and increase their clinical applicability for diagnosis and evaluation of medical problems. Several multimodal medical image fusion algorithms and devices have shown great progress in improving the accuracy of clinical decisions based on medical images. This overview classifies the process of fusioning of medical image research based on his three factors:

(a) commonly used image fusion methods,
(b) relevant imaging modalities;
(c) Organ examined.

Despite numerous open technical and scientific challenges, medical image fusion process has shown encouraging results in augmenting the clinical dependability of medical images for diagnostics as well as analysis. It is a rapidly growing scientific area with the potential for significant advancements in the future years The fusion of medical images controls the noteworthy and complementary information of various images those are retrieve from the different sources that used for identify the diseases and better treatment.

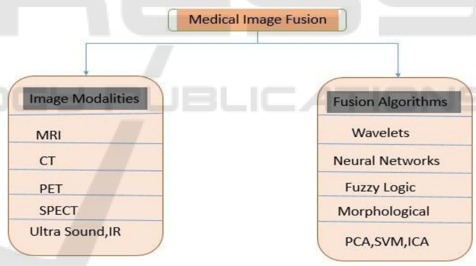

Figure 3: Modalities and Algorithms of image fusion studies.

The field of medical image analysis is distributed into six different categories as depicted below:

Table 1: Categories of Medical Image Analysis.

Categories	Description
Post-acquisition	Prior to diagnosis, images are often subjected to preprocessing techniques such as denoising and renovation to improve their quality and make them usable.
Segmentation	The accurate diagnosis of medical images such as CT scans of abdomen or MRI scans of brain which requires the identification and definition of important features, such as organs, within the image. This process, known as delineation, is crucial for effective analysis and interpretation.
Registration	The process of registering or aligning captured images with a model or previous image is a crucial requirement in computer-assisted surgery.

Computation	In various computer-assisted therapies, there is also a need for the calculation of physical quantities and the execution of additional computational tasks such as fusion and compression.
Visualization	It is crucial for medical images to be displayed, so that medical professionals can accurately diagnose diseases.
Security	Personal medical health information is highly sensitive and must be properly secured through methods such as watermarking. This ensures that only legal users have access to the information and that it is accurately linked to the correct medical record for the appropriate patient.

Medical image fusion can be categorized as shown below: -

1.) Multi View Image Fusion: In this fusion images are taken from different viewpoints but have same modality and at the same time.

2.) Multi Modal Image Fusion: In this fusion different sensors like CT, MRI and PET etc. are used to collect the images (IJARIIE, n.d.). Clinical precision are improve by using the Multimodal medical image fusion algorithms and devices.

3.) Multi Temporal Image Fusion: In this type of fusion, images are extracting at different times for finding the changes between images.

4.) Multi Focus Image Fusion: In this type of fusion images are taken from a 3D scene continually with various focal lengths (Mishra and Bhatnagar, 2014).

2 LITERATURE REVIEW ON MEDICAL IMAGES

P. James and B.V. Dasarathy (James and Dasarathy, 2014) stated that multimodal fusion of medical images has shown significant improvement in clinical diagnosis of disease. Fusion using Multimodel of medical images has shown great improvement in clinical diagnosis of disease. This review article provides practical techniques and summarizes the challenges in medical image fusion. In this white paper, while there are numerous scientific challenges and open technologies available, medical image fusion is a highly useful technology for improving clinical consistency, identification, and analysis.

Daniel Ruijters (Ambrosini et al., 2017) proposed that medical scanning technology gives a wide spectrum of valuable and harmonizing information about a patient's physiology, anatomy and pathology, but the optimal exploitation of this wealth of information is a tough job.

Deron Rodrigues et al., (Rodrigues et al., 2014) have explained that image fusion has become important part in medical field for diagnosis or analysis of disease. The paper describes the introduction of image fusion methods by using wavelet transform and the comparison between the performance of the various types of wavelet basis families used.

Hari Om Shanker Mishra and Smriti Bhatnagar (Mishra and Bhatnagar, 2014) have explained that fusing techniques are used for image enhancement in several imaging techniques like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI).

Hiral Rameshbhai Patel and Raviraj Chauhan (IJARIIE, n.d.) proposed a decomposition and reconstruction method to improve image quality. The Discrete Ripplet Transform is an advanced directionality and localization transform for such edges, and the combination of DWT and DRT yields better images than DWT.

Jan Flusser et al. (Zitova and Flusser, 2003), stated as fusion process of various images is used in numerous applications, such as astronomy, multi-sensor fusion, medical imaging, military, remote sensing, security and surveillance fields. used in these applications. Image fusion is used in many applications such as remote sensing and medical fields, and this pattern is primarily used in CT and MRI images where the more accurate the image, the more useful the information. Many approaches have been developed for medical image fusion.

M.D. Nandeesh and Dr. M. Meenakshi (Casey and Damper, 2010) studied about image fusion techniques with their performance evaluation analysis. They used Discrete Wavelet Transform, Curvelet Transform, Principle Component Analysis, Stationary Wavelet Transform techniques etc.

Madhusmita Sahoo (Ambrosini et al., 2017) explains a modern fusion method to enhance the information content of the fused image. The technique uses wavelet transform, maximum selection rule, windowing technique and GLCM based segmentation.

Mc Cassey et, al. (Casey and Damper, 2010) uses image fusion algorithm to acquire the sincere feasible depth-of-field in macro-photography by using typical digital camera images. Macro photography has some primary problems, one of the most critical is the difficulty of insufficient lighting. Mayank Agrawal et al. (Agrawal et al., 2010) proposed a fusion algorithm for multispectral magnetic resonance imaging that preserves both component and edge information and provides better performance associated to existing fusion algorithms.

Medha Balachandra Mule and Padmavathi N.B (Kotian et al., n.d.) have done analysis of different medical imaging modalities used in fusion. They have explained and compared different image fusion techniques using the quality metrics Peak Signal to Noise Ratio (PSNR) and Root Mean Square Error (RMSE).

Nayera Nahvi and Deep Mittal (Niranjan and Patel, n.d.) have explained a new algorithm for multimodal medical image fusion based on DWT technique. The algorithm escalates the quality of multimodality medical image fusion and the output reveal the efficiency of fusioning process.

P.Ambika Priyadharsini and M.R. Mahalakshmi (Priyadharsini et al., n.d.) proposed that SVD is a substitute image fusion method, which improves the content of medical images by merging two or more multimodal medical images.

Paul Hill et al. proposed DT-CWT (Hill et al., 2005) techniques for image fusion in remote sensing, robotics and medical applications. This method gives better qualitative and quantitative output compared to previous wavelet fusion techniques.

Periyavattam Shanmugam Gomathi and Bhuvanesh Kalaavathi (Gomathi and Kalaavathi, 2016) states a comparative study of image fusion of MRI and CT images based on various wavelets transforms techniques is performed. The final fused image is tested by using many performance metrics to evaluate which wavelet gives the best output.A new generation of high resolution satellite images with less than 1 meter spatial resolution in panchromatic mode is now available. This paper compares the output of three different techniques to fuse the multispectral information and panchromatic data of Quick Bird satellite imagery.

Richa Singh et al. (Lawson et al., 2020) proposed a fusion algorithm that uses Redundant Discrete Wavelet Transforms to combine pairs of multispectral magnetic resonance imaging such as Proton Density, T2 and T1 brain images.

Helonde and Prof. M.R. Josh (Holende et al., 2010) explained that image fusion plays an important role in digital image reconstruction as re-processing steps. Medical image fusion helps in easy diagnostics and reduces the time gap between the diagnosis of the disease and the treatment.

Dr. S. Manikanda Prabu et al. (Prabu and Ayyasamy, 2014) used Lifting Wavelet Transform (LWT) based three different medical image fusion approaches and performed comparative analysis. The IAV method was found to be more suitable for medical image fusion than other approaches in wavelet domain.

Walid Aribi et al. (Arabi et al., 2012), developed new methods to evaluate the quality of medical images based on the multi resolution fusion. These methods are evaluated by objective technical quality.

Zhi-haiXu et al. (Jing, 2009) proposed a new fusion algorithm based on wavelet transform by analyzing the three fusion operators. The algorithm was validated by CT/PET images.

Zhijun Wang et al. (Wang et al., 2005) presented a complete outline of the General Image Fusion (GIF) method is a useful framework for categorizing and evaluating image fusion methods. One such method is MRAIM, which stands for Multiresolution Analysis-based Image Fusion using Morphological Reconstruction and Iterative Method.

The field of Image-Guided Therapy (IGT) is rapidly growing and has seen success with the commercialization of advanced IGT systems by several small companies. However, in meetings between IGT investigators, it was determined that there are several key areas that require collaborative effort from the community to improve patient care.

Image fusion is an interesting field for the researcher. Various techniques like wavelet transform HIS and PCA based methods are proposed by many author or researchers.

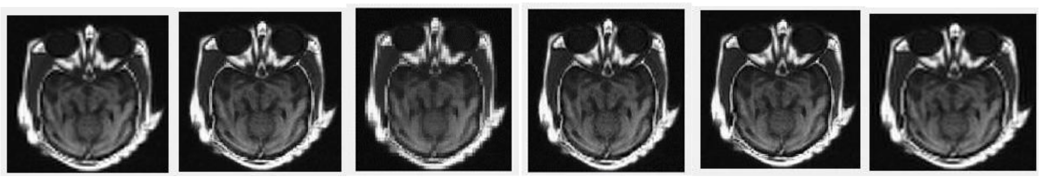

Figure 4: Fusion of MRI and CT Image a) Using Daubechies(db) b) Using Coiflets (coif)c) using Bi-orthogonal (bior) d) By Symlets (sym) (e) By Reverse Bior (rbio) (f)By Discrete Meyer (dmey).

Table 2: Different Fusion Strategies.

METHOD	TYPE OF IMAGE	FUSION STRATEGIES
MORPHOLOGY KNOWLEDGE	MRI, CT, ULTRA SOUND, MAMMOGRAM, PET	MORPHOLOGY FILTERA, LEARNING SYSTEMS, EXPERT SYSTEMS
WAVELETS	CT, PET, MRI, ULTRA SOUND, SPECT	DISCRETE WAVELET TRANSFORMS, STATIONARY WAVELET, MULTI-WAVELET TRANSFORM
ANN	CT, PET, MRI, ULTRA SOUND, MRA, SPECT	NEURAL NETWORKS, CLUSTERING NEURAL NETWORKS
FUZZY LOGIC	CT, PET, MRI, ULTRA SOUND, MRA, SPECT	IMAGE FUZZIFICATION, DEFUZZIFICATION, NEURO FUZZY NETWORKS,

3 CONCLUSION

The field of medical diagnostics and monitoring is rapidly advancing with the growth of latest technologies and scientific advancements. However, the use of medical images to aid in these processes is not without challenges. These challenges can be technological, scientific, and societal in nature.

One of the challenges is related to the quality of imaging features. In order to achieve a comprehensive understanding of a medical condition, multiple imaging modalities are often used. However, these modalities may produce images with different qualities and characteristics. Image fusion techniques can be used to improve the quality of imaging features by integrating information from multiple modalities.

However, the key challenge in applying image fusion algorithms to medical images is to confirm that the medical relevance is maintained and that they aid in achieving enhanced clinical outcomes. This requires careful consideration of the specific medical application, as well as the imaging techniques used.

Despite these challenges, image fusion techniques hold great promise for improving the quality of medical imaging and aiding in diagnostics and monitoring of medical conditions. As such, ongoing research in this area is critical for the advancement of medical science and for the betterment of patient care.

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