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Application and Trends of Image Fusion: Challenges and Case Study of Wavelet Fusion

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***Abstract:* In recent years, a variety of technical domains and industries have been included in the scope and applications of image fusion algorithms. The most recent techniques and developments for boosting the effectiveness of fusion methods have been discussed in this article. The study examines the application of deep learning and augmented reality to image fusion. The purpose of the study is to review prospective research fields, point out challenges, and describe breadth.**

***Key words:* Wavelet fusion, satellite navigation, visual surveillance, and medical imaging.**

I. INTRODUCTION

Image fusion is the process of combining many photos of the same location to create a single image that contains the best features of each shot. This could be done for a number of purposes, including improving an image's spectrum knowledge, expanding its resolution in space, or lowering noise. The ideal picture fusion strategy depends on the specific application. A based on features fusion is typically employed for situations in which accuracy in space is essential .Instances when the use of intensity-based fusion is required due to the significance of the spectrum data occur frequently. Wavelet-based fusion is widely used in applications where both depth and spectrum knowledge are crucial. Although innovation remains in its infancy, neural network fusion has showed promise for some remote sensing applications. Fusion is a useful technique for improving the aesthetic attractiveness of remote sensing imagery. It could be used to improve the images' spatial accuracy, noise reduction, and spectrum data. Image fusion is advantageous in many remote sensing uses, such as the categorization of land shelter, the identification of shifts, and the tracking of disasters. The field of picture fusion research is growing swiftly, and fresh approaches are always being developed. As these methods continue to develop, image fusion will become an even more powerful tool for remote sensing applications.

II. WAVELET BASED IMAGE FUSION

Wavelet-based picture fusion is one popular approach to image fusion. A mathematical procedure called a wavelet can be used to split a single picture into several of smaller pictures with different scales. Because of this, different levels of detail can be recreated for each of the image's components.

There are numerous variations of wavelet-based picture fusion methods. The most prevalent algorithms may include:

- The geographically based Fourier fusing method is used to integrate the source images' wavelet decomposition coefficients at the same resolution.
- Frequency wavelet fusion is a technique that integrates the wavelet coefficients from sources with different resolutions.
- In this method, the wavelet coefficients that are calculated for the original images are combined at various levels.

The algorithm to utilize is determined by the specific application. If resolution of space is important, for example, spatial wavelet fusion is widely used in picture fusion. Bandwidth sector wavelet fusion is widely utilized in picture fusion settings where spectral information is important. Multi-scale waveform fusion is often employed for image fusion jobs where combining the spatial spectrum information is essential.

Advantages of wavelet Fusion

Wavelet-image fusion has a number of benefits over earlier image fusion methods. These advantages include:

• It can deal with photos of various spectral qualities and resolutions.

• The input photographs' edges and features can be kept.

• It is used to remove noise from photographs.

• It has good computational speed.

Disadvantages of wavelet Fusion

There are a few issues with wavelet-based image merging as well. It may be vulnerable to the wavelet basis selection, among other drawbacks For huge photos, the expense of computing may be high.

III. APPLICATIONS OF FUSION

There are several uses for picture fusion; the most popular recent ones are shown in Figure 1.

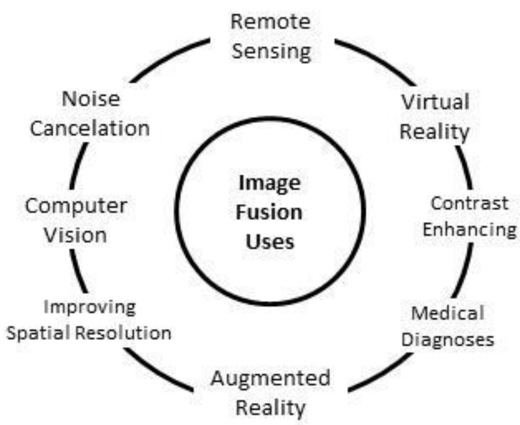

Fig.1. Frequent Recent Application of the Image Fusions

- Increasing the spatial accuracy of a picture by combining a tiny multidimensional image with an excellent quality panchromatic image. High spatial detail is provided by the panchromatic image, whereas spectrum data is provided by the multifaceted photograph.
- Increasing an image's spectral detail: This may be achieved by combining a number of multispectral photos with various spectral bands. This might be helpful for figuring out various land cover kinds or for spotting environmental changes.
- Reducing noisy in the following picture: This can be accomplished by combining two or more photos with various noise properties. This can help an image's quality so that it can be processed or analyzed further.

For mapping, a variety of image fusion algorithms are available. The most popular methods include the following:

Feature-based fusion: This method combines the edges, materials, and other characteristics of the input images.

Strength-based fusion: This method merges the input pictures' values for intensity.

Fourier-based fusion: In this method, the input images are broken down into wavelet coefficients, which are then fused.

Profound training-based fusion: In this method, the input images are combined using machine learning techniques.

The success of wavelet-based photo fusion has been proved by a variety of applications, include the ones that follow:

A. Remote sensing

The act of integrating two or more photographs of an identical scene obtained by multiple sensors into one picture that includes the best qualities of each image is known as combining images for remote sensing. This may be accomplished for a number of reasons, including: The following are some instances of picture fusion in remote sensing:

In order to generate a high-resolution photograph using the spectrum data of the multispectral image, pan sharpening involves fusing an excellent quality panchromatic photograph with a tiny multidimensional image. Satellite photos can be made useful for purposes like change detection and vegetation categorization by using pan sharpening to enhance their visual quality. S*pectrum enhancement:* In order to enrich the spectrum data of the fused image, a number of multispectral in nature photographs with various spectral bands are combined. To distinguish between various types of land cover or to spot environmental changes, spectral enhancement is applied.

Interference suppression: To increase the level of detail of the fused image, two or more photos with various noise characteristics are combined. Remote sensing images are enhanced visually and are better suited for extra processing or analysis when noise is suppressed.

B. Medical imaging

The technique of integrating multiple photographs of the same item or scene captured using various types of medical imaging into one picture that includes the best qualities of each image is known as image merging for healthcare image processing. This might be accomplished for a number of reasons, including:

Artefact reduction can be accomplished by merging two photos with various artifacts. This can help an image's quality so that it can be processed or analyzed further.

- Improving diagnosis precision: This may be achieved by combining images from other modalities that offer additional information. For better visualization of tumors and other anomalies CT and MRI scans can be combined.

The processing of medical images can make use of a wide variety of image fusion techniques. The pixel intensities of the input images are fused using an intensity-based fusion approach. The most basic and most typical kind of image fusion is this one. The edges and colours of the input photos are combined using the feature-based fusing technique. For maintaining the minute details of an image, this may be superior to intensity-based merging. In a harmonic-based fusion method, the input images are broken down into wavelet coefficients, which are then fused. For reducing noise and artifacts, this may be more successful either intensity-based or feature-based techniques fusion. The input photos are fused using deep learning techniques in the deep learning-based fusion technique. Although it is still in the early stages of development, this method has showed promise for a number of medical picture fusion uses.

The particular application determines the best picture fusion approach. For situations where the accuracy of spatial resolution is crucial, for instance, intensity-based fusion is frequently used. Systems where the small details of a picture are crucial frequently use feature-based fusion. Systems whereby noise cancellation and artifact reduction are crucial frequently use wavelet-based fusion. Although it is an approach that is still in development, deep learning-powered fusion has showed promise for a number of medical picture fusion uses.

Several applications of healthcare image processing can use image merging, including:

- Surgery organizing: By merging images from many modalities, fusion of images can be utilized to design complex procedures. This can aid doctors in planning the best course of action for the surgery and in visualizing the patient's anatomy.
- Diagnosis: By merging images from many modalities, the combination of images can be utilized to diagnose disorders. This can aid medical professionals in spotting anomalies and providing more precise diagnosis.
- Treatment tracking: By integrating photos from several time periods, the combination of images might be

utilized to track the development of a treatment. This can assist medical professionals in evaluating the efficacy of the medication and making any necessary modifications.

- Research: combining images can be utilized to study ailments and remedies. This could aid in the development of new diagnostic and therapeutic techniques as well as researchers' understanding of the physiological and anatomical makeup of the human body.

C. Industrial inspection

In corporate examination, a process called image fusion is utilized to merge many photographs of the same item or scene captured from various angles. By combining images from many sensors that offer complimentary data, fusion is utilized to improve the accuracy of fault detection. For better metal part flaw detection, for instance, visible light and infrared camera pictures can be combined. A fusion applications used to monitor the caliber of produced products is control of quality. For instance, combination of images may be used to guarantee that a product's dimensions are within tolerance. One of the main uses for image fusion could be process monitoring, which tracks how well the production process is going. For instance, a fusion of pictures can be used to monitor a product's progress by means of a line of manufacturing.

D. Surveillance Image

Fusion is a technique used in cctv to merge several photographs of the same environment captured by various sensors or views into one picture that combines the best elements of all the images. The accuracy of target detection can be improved by combining images from many sensors that each give complimentary data. For better target recognition in low light situations, for instance, images from regular light and infrared cameras can be combined Target detection in various situations, such as darkness or bad weather, can be accomplished using image fusion. Target tracking can be done via image fusion. Another use is for observation of broad areas, such roadways in cities or airports. Monitoring security at important facility locations is the only significant use from recent times.

E. Computer vision (CV)

In CV, a technique called image fusion is employed to increase the precision of identifying objects methods. For better object detection in low light, for instance, images from visible light and infrared cameras can be combined. To make scenes easier to grasp is another application. For instance, combining photos from multiple cameras may be beneficial to produce a scene that is more precise and comprehensive.

IV. RECENT WORK

There are several methods for combining the photos. The classification of the most popular techniques is depicted in Figure 2.

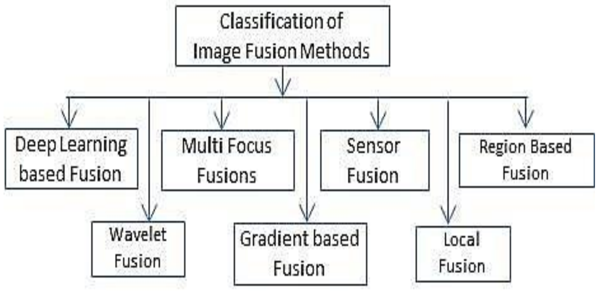

Fig.2. Classification of the Image Fusion

Kaur and co [1] in there paper discusses numerous state-of-the-art picture fusion techniques at various levels, along with their benefits and drawbacks, as well as various spatial and transform-based techniques with quality measures and their applications in many fields. This review has finished with a number of future directions for various image fusion applications. Jiao, Du, et al. [2] work on the SF concept is first expanded by adding two diagonal SFs, a reference SF (SFR) is computed from the input images, and the error SF (SFE), or the ratio of SF error (rSFe = SFE/SFR), is used as a fusion quality metric. The direction of the fusion error—over-fused (if rSFe > 0) or under-fused (if rSFe 0)—is indicated by the rSFe, which can be positive or negative.

Meher and others an overview of region-based fusion techniques is presented in this study. The classification of region-based fusion techniques is done directly. To compare the existing approaches, a thorough list of impartial evaluation measures for fusion is presented. The results of a thorough analysis are presented in tabular form. This might entice scholars to pursue this line of inquiry further.

Nie and co. preseted recent advances in deep learning techniques for remote sensing image fusion are discussed in this chapter. The various deep learning networks that are used are described first. Their training process is also discussed. The use of deep learning models to the fusion issue is then thoroughly explained. To that goal, a number of illustrative techniques are initially mentioned.

Pan and co. addressed pan-sharpening problem was addressed in this study using the innovative deep perceptive patches generative adversarial network (FDPPGAN). The first step was building a perception generator, which had a matching module that could handle images of varied resolutions as input, a fusion section, a rebuilding module employing the residual framework, and a module for extracting perceptual elements. In order to guarantee that the obtained results can maintain more intricate details, the dichotomy of the sample was converted into numerous partial pictures using a patch discriminator.

Junli Zhao and others studied fusion effect, image detail clarity, and time effectiveness can all be significantly enhanced by the suggested strategy. The studies on multi-modal medical images are conducted to evaluate algorithm stability, performance, and other factors. The results of the experiments show that our

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suggested strategy is superior in terms of visual quality and a number of quantitative evaluation parameters. This has been accomplished using Discrete Wavelet Transformation (DWT) and Principal Component Analysis (PCA), according to Mishra et al. In the suggested fusion method, the first principal component (PC) of the LRMS image is extracted while the PAN image is simultaneously transformed morphologically.

Chen et al., Li, X. researched and uses the built-in sensors of a virtual reality head-mounted display (VR HMD), RGB cameras, and human position estimation to collect three modalities of nine activities from VR users. These data, along with cutting-edge multimodal fusion action recognition networks, allowed us to create an action recognition model with a high level of accuracy.

Mladenovic and others presented a chapter discusses the potential applications of augmented reality (AR) and artificial intelligence (AI) in dental practice and education now, as well as the potential directions these technologies may go in the future. Artificial intelligence (AI)-driven dental technologies that incorporate augmented reality and virtual reality are quickly developing into practical clinical practice solutions and closing the gap between the digital and physical worlds.

Xiao et al. designed by squeeze-and-decomposition network (SDNet), multi-modal and digital photography picture fusion is made possible in this article in real time. In order to develop a universal type of loss function that is made up of an intensity term and a gradient term, we first usually translate numerous fusion issues into the removal and rebuilding of gradients and intensity information.

Youyong Zhou and others techniques that use boundary segmentation were presented as a group of image fusion algorithms in this research. As a result, four new classification techniques for image fusion algorithms are suggested: transform domain, boundary segmentation, deep learning, and combination fusion. Eight typical objective evaluation signs are presented in detail, along with a summary of the subjective and objective evaluation standards.

V. CASE STUDY OF MULTI FOCUS IMAGES FUSION

This case study fuses the multi focus images of same object or scene using the wavelet fusion approach. A hybrid wavelet fusion rule is used for the evaluation.

a) Showpiece image 1 b) showpiece image 2

c) Clock image 3 d) clock image 4

Fig.3. Multi-Focus image used for case study

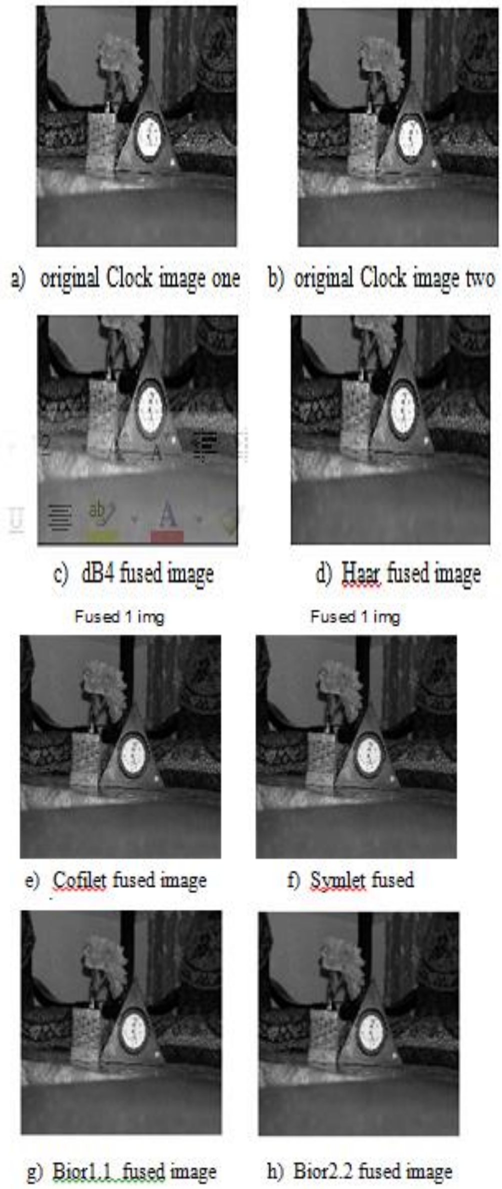

Fig.4.Results of wavelet filters for Clock 3 Image

The wavelet based fusion results are preseted for the different kind of wavelet filters in the Figure 4 for Clock image 3, and Result of fusion for the Results of wavelet filters for Drawing room image is preseted in the Figure 5 respectively. The images are converted to the gray level image and then wavelet fusion of 2 levels is applied on the mages. The filters under consideration re Haar, DB2, bi orthogonal 1 and 2 order, cofwlwt and symlet filters.

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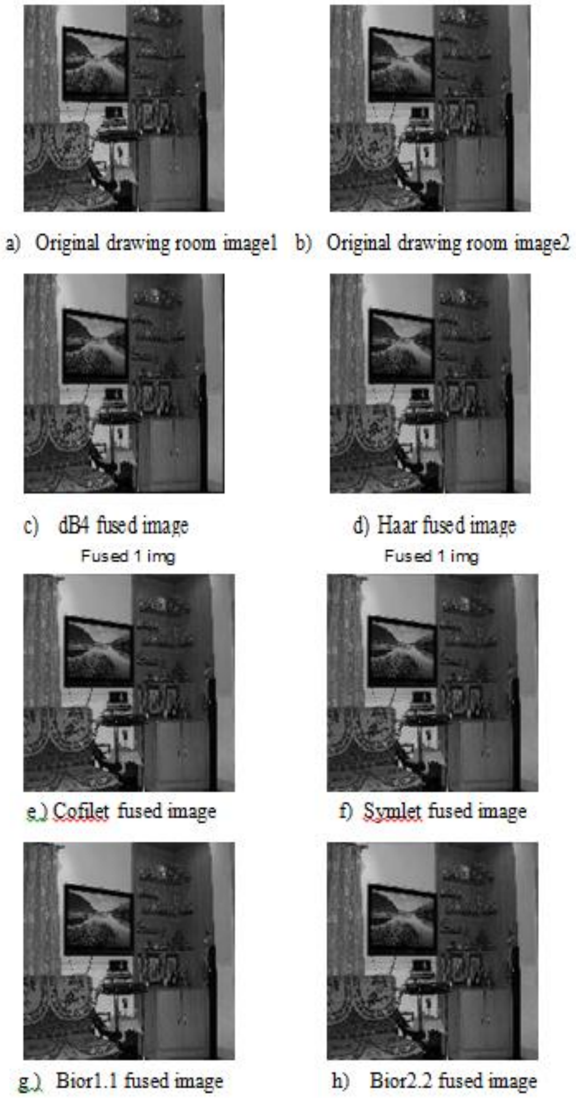

Fig.5. Results of wavelet filters for Drawing room image

VI. CONCLUSION

The study of image fusion is expanding quickly, and new and innovative ways are constantly being created. Combining images is going to be an increasingly more potent tool for processing medical images applications as these methods continue to advance. A strong and adaptable image fusion method is wavelet-based picture fusion. It has been proven successful in a number of applications.

For a given application, it is crucial to select the appropriate wavelet foundation and algorithm. The prospects for image fusion are promising. New and enhanced picture fusion methods will be created as this field of study progresses, allowing for superior results across a wider variety of uses.

There are particular Future uses for Fusion include the use of augmented and virtual reality, and the capacity for real-time processing to combine pictures. In a number of applications, algorithms based on deep learning have showed promise for enhancing the efficiency of picture fusion methods.

Self-driving cars can perform better by adopting image fusion, which combines images from many cameras to get a deeper and more precise view of the path ahead. When it comes to security, photo fusion may be utilized to combine photos from many cameras to better detect attackers.

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