A Detailed Survey of Multi Focus Image Fusion

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ABSTRACT

Multi-focus image fusion is a crucial aspect of image processing, aimed at enhancing the overall visual quality and information content of images captured at different focal planes. This paper presents a comprehensive survey of various techniques and methodologies employed in the domain of multi-focus image fusion. The paper begins by explaining the fundamental concepts and challenges associated with image fusion. It then proceeds to categorize existing methodologies of image fusion. Then it explains about multi focus image fusion and with their types and recent proposed techniques developed by researchers. Furthermore, the survey evaluates the strengths and limitations of each technique, providing insights into their applicability under varying conditions. This survey serves as a valuable resource for researchers, practitioners, and enthusiasts interested in the advancements and trends in multi-focus image fusion. By synthesizing and organizing the vast array of techniques available, the paper aims to facilitate a deeper understanding of the subject and inspire further innovation in the pursuit of optimal solutions for multi-focus image fusion challenges.

Keywords

Multi focus, Image Fusion, image processing, medical imaging

1. INTRODUCTION

Image processing encompasses the utilization of diverse techniques and algorithms for the manipulation and analysis of digital images [1]. This field involves a broad spectrum of operations, which are designed to enhance, compress, interpret, and extract information from images. The application of these operations extends to various types of visual data, including photographs, illustrations, medical images, satellite images, and more. A representation of the stages in an image processing workflow is commonly depicted in an image processing diagram, illustrating the sequential or parallel steps involved [2]. The following is a simplified overview of the stages in an image processing workflow, as presented in figure 1.

Image Acquisition- The cycle starts with catching an image utilizing gadgets like cameras, scanners, or sensors. This step includes changing over genuine scenes into advanced portrayals.

Image Pre-processing- Image pre-handling includes a progression of tasks and strategies applied to crude or gained images before their utilization in examination, understanding, or further handling.

Segmentation- Partitioning the image into areas or fragments in view of attributes like color, surface, or force.

Object Detection or Recognition- Object Discovery/Acknowledgment Perceiving and distinguishing explicit items or examples inside the image.

Feature Extraction and Selection- Image feature extraction and choice are key stages in image handling and PC vision. These cycles include recognizing and disconnecting significant and applicable data from images, which can be used for examination, acknowledgment, or grouping assignments [3]. Feature extraction alludes to the most common way of recognizing and removing explicit examples, designs, or characteristics from images that address significant data.

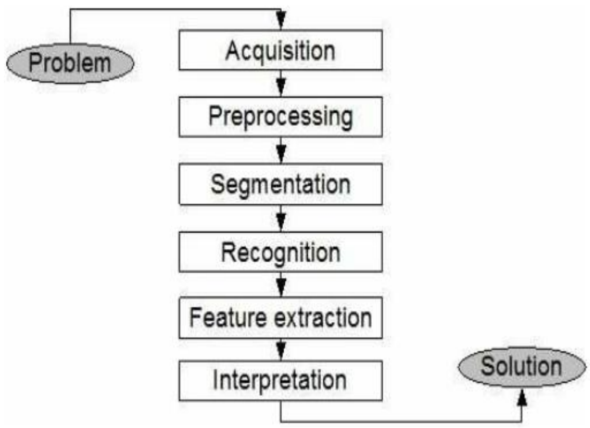

Fig 1: Steps of a digital image processing system

Image Interpretation- Image understanding includes breaking down and grasping the substance, setting, and meaning of visual data inside images. It's a mental interaction where people or mechanized frameworks remove significance, induce connections, and make informed ends in view of the visual substance introduced.

Interpreting Results- Investigating the handled image to extricate significant data or reach inferences in view of the planned application.

Decision Making- Utilizing the handled data to simply decide or perform further activities in view of the broke down data.

Visualization- Showing the handled image or its examination results for human translation or for additional handling in ensuing stages.

2. IMAGE FUSION

Image fusion in image handling alludes to the most common way of consolidating various images from various sources or modalities to make a solitary composite image that contains more extensive or improved data than any of the singular information images [4]. The objective is to use the qualities of each image to create a more instructive, clearer, or better portrayal. Image fusion implies the joining of two images into a solitary image that has the most extreme data content without delivering subtleties that are non-existent in the given images [5]. With fast progressions in innovation, it is presently conceivable to get data from multi source images to deliver an excellent combined image with spatial and unearthly data.

Image Fusion is an instrument to work on the nature of data from a bunch of images.
There are three essentials steps which are completed during the time spent image fusion. These means are referenced in figure 2.

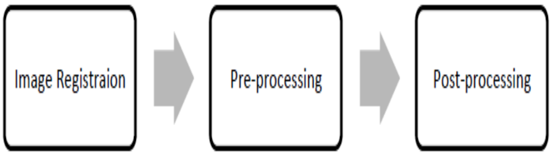

Fig 2: Image Fusion Basic Steps

Image Registration- The course of image enrolment adjusts the succession of images to cover the comparing features and subtleties accurately.
Pre-Processing- In the method of image fusion, the fundamental point of this step is to make the images more appropriate for the calculation of image fusion.
Post-Processing- This step is essentially reliant upon the sort or class of the presentation being utilized in the fusion cycle. One more trustworthiness of this cycle includes the tendency of a human administrator.
Significant utilizations of the fusion of images incorporate clinical imaging, minuscule imaging, remote detecting, PC vision, and advanced mechanics. These strategies are displayed to perform far superior to basic averaging, most extreme, least. The essential objectives of performing image fusion strategy can be dissected in the chart of figure 3.

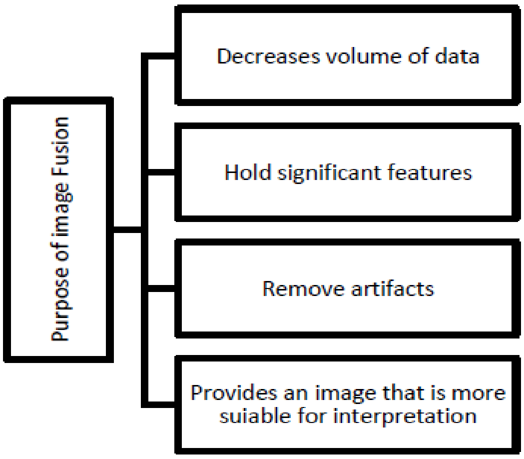

Fig 3: Aim of image fusion

Articulations like mixture, stage, cooperation, joining, and various extra ideas that direct further or less the same thoughts have since appeared to be in the fiction [6]. In the use of remote detecting common, the succeeding portrayal has been embraced: "A proper system where means and devices for communicating the collusion of data are starting from various sources called Data fusion.

3. CLASSIFICATION OF IMAGE FUSION

Image fusion can be extensively characterized as the most common way of brushing different information images or a portion of their features into a solitary image without the presentation of mutilation or loss of data. The point of image fusion is to coordinate corresponding as well as repetitive data from various images to make a melded image yield as displayed in figure 4. In this way, the new image created ought to contain a more precise depiction of the scene than any of the singular sources images and is more reasonable for human visual and machine discernment or further image handling and examination undertakings [7]. Image fusion is a valuable strategy for blending comparative sensor and multi-sensor images to improve the data content present in the images. Three distinct conventional data fusion are Feature level, pixel level and choice level. These go under the fusion of data order.

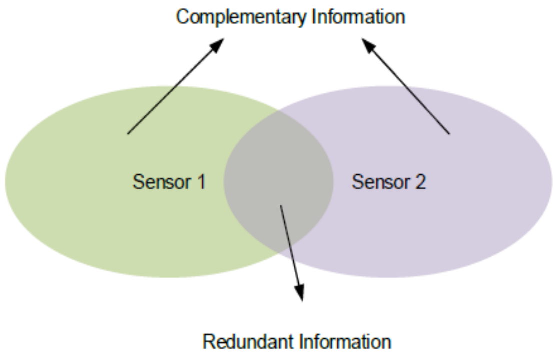

Fig 4: Image fusion example

In any case, this strategy normally prompts unwanted after effect like diminished contrast. More vigorous calculation for pixel level fusion is the weighted typical methodology. In this technique, the melded pixel is assessed as the weighted normal of the comparing input pixels. Be that as it may, the weight assessment normally requires a client explicit edge. Since this present reality protests for the most part contain structures at a wide range of scales or goals and multi-goal or multi-scale approaches can give a way to take advantage of this reality. The multi-goal procedures include two sorts, one is pyramid change; another is wavelet change. In the pyramid fusion, the info images are first changed into their multi-goal pyramid portrayals. The fusion cycle then makes another combined pyramid from the info image pyramids in a specific fusion rule. The intertwined image is at long last reproduced by playing out a backwards multi goal change. Instances of this approach incorporate the Laplacian pyramid, the slope pyramid, the difference pyramid, the proportion of-low-pass pyramid, and the morphological pyramid. Notwithstanding, for the explanation of the pyramid technique neglects to present any spatial direction selectivity in the decay cycle, the previously mentioned strategies frequently cause hindering impacts in the fusion results [8].
Image fusion can be done in three levels as described in the figure 5 below.
Low or pixel level- The pixel-level technique works either in the spatial area or in the change space. Image fusion at pixel level adds up to reconciliation of low-level data, by and large actual estimations like power. Pixel level fusion can be utilized to build the data content related with every pixel in an image framed through a mix of different images [9].

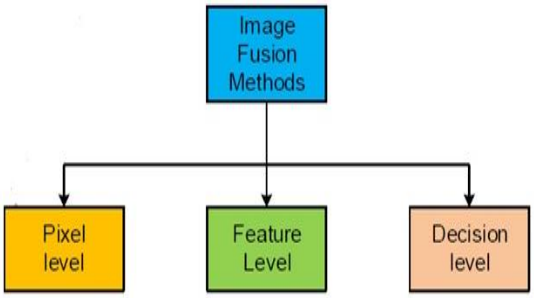

Fig 5: A generic classification of image fusion methods

Middle or feature level- Feature level fusion requires first extraction of the features; those features can be distinguished by qualities like differentiation, size, shape and texture. Feature level image fusion procedure can be additionally ordered into AI, district based and similitude matching to content based. In the AI technique, the features are removed and a reasonable classifier is utilized for fusion. In locale based strategy, the info images are isolated into various districts utilizing some division procedures. **High or decision level-** Choice level fusion involves the results of introductory article identification and characterization as contributions to the fusion calculation to play out the data joining.

4. MULTI-FOCUS IMAGE FUSION

Multi-focus image fusion is a computational technique employed to integrate information from multiple images captured at varying focal planes into a single composite image [10]. Traditional cameras often struggle with limited depth of field, causing some parts of a scene to be in sharp focus while others remain blurred. In scenarios where a comprehensive view with clear details is crucial, such as medical imaging, remote sensing, and surveillance, multi-focus image fusion becomes essential. This process involves combining images obtained from the same or different modalities to create a fused image that retains focused details from various focal distances. The aim is to generate a comprehensive image that overcomes the limitations of individual frames, providing both high spatial and spectral resolution. Researchers have proposed and developed numerous techniques and algorithms to address the challenges associated with multi-focus image fusion [11]. These techniques aim to enhance the interpretability of images for both human and machine analysis, facilitating more effective decision-making in various applications. The reduction in costs is achieved through image fusion, eliminating the need to transmit multiple images of the same scene with different focal points. Instead, a single, all-in-focus image is transmitted. A typical multi-focus image fusion algorithm involves estimating a focus map for each input image, categorizing pixels as focused or defocused. These maps then guide a fusion rule, ultimately generating an all-in-focus image [12]. Figure 6 illustrates the block diagram of such an algorithm.

Multi-focus image fusion has garnered substantial research attention recently, leading to the development of numerous techniques [13]. The resultant image got is a combined image which is having every one of the items in-focus and is named as Multi-Focus Image Fusion (MFIF). The course of MFIF is displayed in Figure 7.

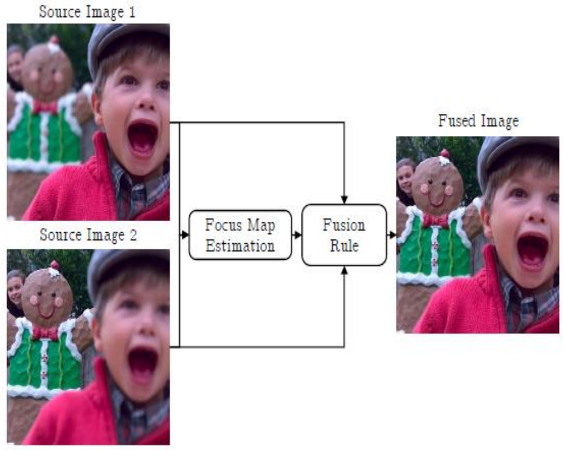

Fig 6: General image fusion process using two multi-focus images

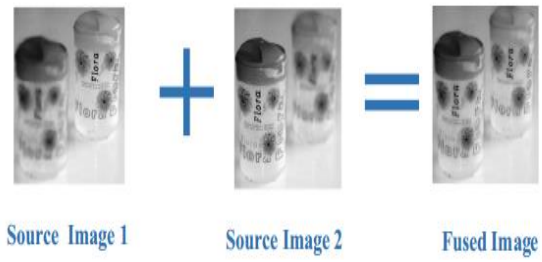

Fig 7: Process of Multi-focus image fusion

MFIF joins multiple source images to get a solitary combined image with additional data and improved highlights than the defocused images. In different terms, it is considered as a fusion method whose goal is to join images of divergent central planes from a comparable scene to get viable fusion results which imply that the melded image has every one of the central planes focused [14]. MFIF permits us to accomplish an image with more exact depiction and subtleties of a scene contrasted with the first images. The central issue of this approach fostering a productive movement level estimation is to ascertain the source image clearness. During the time spent Image Fusion (IF), image enlistment is likewise an exceptionally fundamental essential [15]. The principal objective of image enlistment is adjusting the source images to each other. From the current writing, it has been seen that source images utilized for MFIF should be impeccably adjusted. Notwithstanding, accomplishing this is very difficult progressively circumstances. Multi-focus image fusion is a course of joining at least two to some degree defocused images into another image with all intrigued protests pointedly imaged. There are numerous Multi-Focus Image Fusion Calculations. These calculations are differed, contingent upon whether the information images are combined in the space or in the transform area [16].

5. TYPES OF MULTI MULTI-FOCUS IMAGE FUSION

Image fusion calculations can be arranged into low, mid, and significant levels. In some writing, this is alluded to as pixel, highlight, and emblematic levels [17]. Pixel Level or Sign level Image Fusion addresses image fusion at the most reduced level, where various crude information image signals are consolidated to deliver a solitary combined image signal. Highlight level Image Fusion (otherwise called Item Level Image Fusion), wires component and article marks and property descriptor data that have proactively been removed from individual info images. At long last, the most significant level, Image or Choice Level Image Fusion addresses fusion of probabilistic choice data acquired by neighborhood chiefs working on the consequences of component level handling on image information.

Multi-Exposure Image Fusion- this present reality scenes show exceptionally high unique reaches in glow, variety and focus. Luckily the HVS is prepared to do effectively catching and introducing these images to the human cerebrum which can proficiently meld these images, making an exceptionally serious level of authenticity. Tragically customary computerized cameras are restricted in their capacity as they can not catch the entire powerful scope of glow, variety and focus of this present reality scenes in a solitary shot [18].

Multi-Transient Image Fusion- Fleeting Image fusion coordinates all the while spatial and worldly development of the tracer uncovering data that can't be seen in that frame of mind of one time grouping. Typically unique examinations are performed by drawing physically districts of interest (return for money invested) on an image. This image is looked over changed time acquisitions for showing the ideal differentiation for the given return for capital invested.

Multi-Temporal Image Fusion- Worldly Image fusion coordinates all the while spatial and fleeting development of the tracer uncovering data that can't be seen in that frame of mind of one time succession. Typically unique investigations are performed by drawing physically districts of revenue (return for money invested) on an image. This image is browsed different time acquisitions for showing the ideal difference for the given return for money invested.

Multi-Focus Image Fusion- Because of the restricted focus profundity of the optical focal point, it is much of the time unrealistic to get an image that contains all pertinent articles in focus. In an image caught by those gadgets, just those items inside the profundity of field are focused, while different articles are obscured. To get an image with each item in focus, a multi-focus image fusion process is expected to combine the images taken from a similar view point under various central settings.

Multi-Sensor Image Fusion- The data science research related with the advancement of tactile frameworks focuses chiefly on how data about the world can be extricated from tangible information [19]. The detecting system can be deciphered as a planning of the condition of the world into a bunch of much lower dimensionality. The planning is numerous to one which actually intends that there are normally numerous potential arrangements of the world that might bring about the deliberate tactile information.

6. REVIEW OF MULTI-FOCUS IMAGE FUSION TECHNIQUES

In a series of studies on image fusion techniques, Vakaimalar E et al. [1] proposed the CDSIF algorithm, emphasizing the combination of DCT and spatial frequency to enhance performance and visual quality, outperforming various existing methods. Yong Yang et al. [2] presented a hybrid multi-focus fusion method, addressing subband coefficient selection challenges using NSCT, achieving superior results over transform-based fusion methods. Yu Liu et al. [3] introduced a novel multi-focus fusion method employing a deep convolutional neural network (CNN), demonstrating state-of-the-art results and discussing the potential of CNNs in revolutionizing image fusion research. Subham Mahapatra et al. [4] proposed a DCT-based fusion technique for multifocus images, emphasizing simplicity, efficiency, and improved quality through variance-based contrast measures. Lastly, Hui Wan et al. [6] proposed a multi-focus color image fusion algorithm based on quaternion multi-scale singular value decomposition, reporting enhanced subjective visual effects and good performance in objective evaluation indices, while highlighting the need for efficiency improvements and adaptive parameter selection in future research.

In a series of diverse approaches to multi-focus image fusion, Jinlei Ma et al. [7] introduced an efficient method leveraging two-scale focus maps, utilizing random walks-based estimation to distinguish focused and defocused regions, demonstrating robustness to misregistration and noise. Feng-Ping An and Zhi-Wen Liu [8] proposed an adaptive image processing algorithm, BLMD, based on local mean decomposition, showcasing self-adaptive and multi-scale characteristics, offering targeted solutions for extremum points extraction and decomposition stop conditions. Mostafa Amin-Naji et al. [9] presented a multi-focus image fusion method utilizing singular value decomposition in the DCT domain, demonstrating its effectiveness in both spatial and DCT domains, particularly excelling in noisy conditions. Youyong Zhou et al. [11] provided an extensive classification and comparison of four multi-focus image fusion methods, emphasizing the importance of selecting the appropriate method based on different scenarios and highlighting the advantages of objective evaluation over subjective evaluation. Lastly, Hui Wan et al. [12] proposed a novel multi-focus image fusion method based on multi-scale decomposition of complementary information, achieving accurate discrimination between focused and non-focused areas, even in cases of image pre-registration and unregistration, with superior subjective and objective evaluation indicators compared to existing methods.

In a set of diverse studies on image fusion techniques, Kapil Joshi et al. [13] proposed a scheme based on discrete wavelet transformation for multi-focus image fusion, utilizing variance-based fusion on the approximation part and weighted fusion on detailed parts to enhance focus, demonstrating improved image quality through fusion metrics. Nidhi Taxak and Sachin Singhal [14] focused on improving PSNR and reducing MSE in 2-D image fusion, introducing a Weighted Average Brovery Transform method that outperformed existing methods. Xiaosong Li, Fuqiang Zhou, and Juan Li [16] presented a multifocus image fusion technique incorporating block consistency verification and guided filtering for decision map learning, achieving superior results compared to traditional and state-of-the-art fusion methods. Wei Tang et al. [17] proposed an unsupervised method using a multiscale adaptive Transformer (MATR) for multimodal medical image fusion, demonstrating superior visual quality and quantitative evaluation compared to representative methods. Kanika Bhalla et al. [18] developed an automatic AOI method for laser cutting paths generation, outperforming edge detection methods and deep learning models, offering a convenient and effective solution for LCD panel inspection in the manufacturing industry. Lastly, Shuaiqi Liu et al. [19] introduced an end-to-end mapping learning approach for multi-focus image super-resolution reconstruction, combining degradation models, noise smoothing, and edge preservation, demonstrating enhanced accuracy in detecting focus areas, improved edge space continuity, and competitive computational efficiency.

7. MULTI FOCUS IMAGE FUSION USED IN MEDICAL DIAGNOSIS

Multi-focus image fusion in clinical finding assumes a crucial part in improving the clearness and data accessible in clinical images. It includes consolidating multiple images of a similar scene caught with changing focus settings to make a solitary, in-focus image that contains the most keen and most pertinent subtleties from each information image. In clinical applications, this fusion strategy tracks down use in a few regions:

Microscopy- In minuscule imaging, consolidating images caught at various central planes helps in making a composite image that guarantees generally basic subtleties are in focus. This is especially valuable in pathology, histology, and cell examination.

Endoscopy- Fusion of multi-focus images in endoscopic strategies works on the lucidity of the noticed region, supporting better location and finding of anomalies or sores inside the body.

Radiology- In radiological imaging, for example, X-ray or CT examines, multi-focus image fusion helps with working on the sharpness and lucidity of physical designs, giving more clear visuals to precise conclusion by specialists and radiologists.

Ophthalmology- In imaging strategies like optical lucidness tomography (OCT), blending multiple images caught at various central profundities helps in getting a more extensive perspective on the retina or cornea, helping with diagnosing eye illnesses.

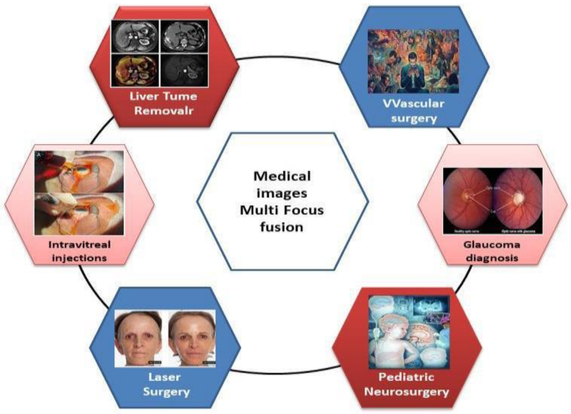

Fig 8: Various multi focus image fusion used in medical diagnosis

Ultrasound Imaging- Fusion of images caught from various central profundities in ultrasound assessments can work on the lucidity and precision of recognizing structures inside the body, supporting diagnostics and observing.

Surgical Planning and Navigation- Multi-focus image fusion can furnish specialists with more itemized and clearer images for pre-usable preparation and intra-employable route, considering more exact intercessions.

8. APPLICATIONS OF MULTI MODEL IMAGE FUSIONS

The various applications of mutinous image fusion are shown in Figure 9. Neurosurgery using MRI and PET data fusion can be employed, as well as the fusion of multiple retina images for ophthalmology analysis to diagnose eye diseases. Another case of retinal image fusion can be for diabetic retinopathy [15].

Another application of fusion is to reliably detect and segment tumors, as well as assess their responses to treatments. Multi-focus image fusion is an effective method for improving the accuracy and dependability of medical diagnosis and therapy. As technology advances, it is bound to have a further impact on healthcare [16]. Multi-model image fusion tracks down applications in different spaces because of its capacity to consolidate data from multiple sources or modalities. The following are a couple of uses:

Medical Imaging- In medical care, consolidating information from X-ray, CT filters, ultrasound, PET sweeps, and other imaging modalities can give an exhaustive view to finding and therapy arranging. Fusion improves the exactness and productivity of clinical imaging investigation.

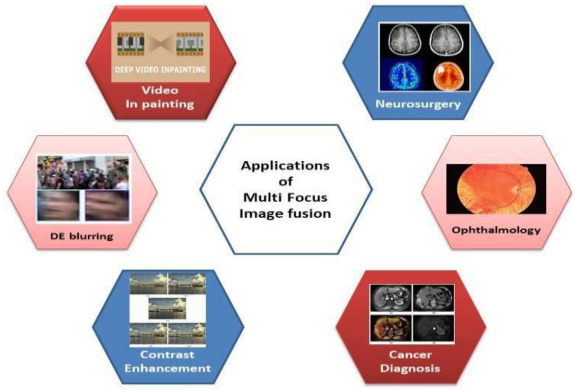

Fig 9: Applications of the Multi model image Fusions

Surveillance and Security- Coordinating information from various sensors like noticeable light cameras, infrared cameras, radar, and lidar further develops object discovery, following, and acknowledgment in reconnaissance frameworks, helping with security applications.

Remote Sensing- Satellite or flying imagery fusion including various groups or goals can further develop land cover arrangement, natural checking, farming appraisal, and calamity the board.

Robotics and Autonomous Systems- For robots and independent vehicles, joining information from cameras, LiDAR, radar, and different sensors helps in better view of the climate, empowering more secure and more exact route.

Augmented Reality (AR) and Virtual Reality (VR)- Fusion methods improve the authenticity of AR and VR by incorporating multiple tactile information sources, furnishing clients with a more vivid and sensible experience.

Image Enhancement- Merging Blending images taken in various lighting conditions or openings helps in making upgraded, more useful, and outwardly engaging images.

Military and Defence- Multi-sensor image fusion helps with target acknowledgment, following, and observation in protection applications by coordinating information from different sources like warm imaging, radar, and optical sensors.

Meteorology and Climate Studies- Joining of information from various weather conditions observing instruments helps with determining, weather condition examination, and environment reads up for a more precise comprehension of climate peculiarities.

Artificial Intelligence and Machine Learning- Multi-model image fusion is utilized to make assorted and more extravagant datasets, empowering artificial intelligence models to learn more extensive portrayals, working on their exactness and heartiness.

Biometrics- Fusion of data from various biometric modalities (like face, unique finger impression, iris, and so forth) can upgrade precision in ID and confirmation frameworks.

Basically, multi-model image fusion assumes a pivotal part across different fields by consolidating the qualities of various imaging modalities to give more thorough, precise, and point by point data for examination and direction.

9. CONCLUSION AND FUTURE SCOPE

In this detailed survey, the paper has explored the diverse landscape of multi-focus image fusion techniques. The analysis presented in this paper underscores the importance of multi-focus image fusion in enhancing image quality and information retrieval in various applications. Our examination of the existing methodologies has revealed a rich tapestry of techniques, each with its own set of strengths and limitations. Traditional methods, such as pixel-based and region-based approaches, offer simplicity and computational efficiency but may struggle in handling complex scenes. As the field continues to evolve, collaboration and knowledge-sharing among researchers become increasingly vital for addressing the remaining challenges and pushing the boundaries of multi-focus image fusion. In conclusion, this survey contributes to the collective understanding of multi-focus image fusion techniques and serves as a valuable guide for researchers and practitioners navigating the diverse landscape of image processing. As the field progresses, the insights gained from this survey can inform future research directions and inspire innovative solutions to further advance the state-of-the-art in multi-focus image fusion.

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