JOURNAL OF AERONAUTICAL MATERIALS
ISSN: 1005-5053

Vol. 43, Issue-01, 2023
pp. 516-524

AUTOMATIC IMAGE REGISTRATION FOR MULTI-FOCUS IMAGE FUSION TECHNIQUE USING SWT AND PCA

D.G. Ramesh Babu
Professor, Department of Electronics and Communication Engineering, Raghu Engineering College, Visakhapatnam, Andhra Pradesh, India – 531162.

Vakkalagadda Sankara Rao
Student, Department of Electronics and Communication Engineering, Raghu Engineering College, Visakhapatnam, Andhra Pradesh, India – 531162.

Jakku Bhanu
Student, Department of Electronics and Communication Engineering, Raghu Engineering College, Visakhapatnam, Andhra Pradesh, India – 531162.

Sodabathina Raghavendra
Student, Department of Electronics and Communication Engineering, Raghu Engineering College, Visakhapatnam, Andhra Pradesh, India – 531162.

Pothala Lalith Kumar
Student, Department of Electronics and Communication Engineering, Raghu Engineering College, Visakhapatnam, Andhra Pradesh, India – 531162.

Abstract: A unique method based on Stationary Wavelet Transform (SWT) and Principal Component Analysis is presented in this work for automatic picture registration in multi-focus image fusion (PCA). The process of picture fusion relies heavily on image registration, which brings together images that were captured at different focal lengths or from different angles and positions. In this research, we offer an automatic registration approach that makes use of feature extraction with SWT and feature reduction with principal component analysis. Multi-focus images with intricate structures and textures are successfully registered using the proposed method. Experiments on multiple datasets corroborate the usefulness of the suggested strategy, and the findings show that our approach outperforms the current state-of-the-art methods. Medical image analysis, remote sensing, and surveillance systems are only a few examples of possible uses for the suggested technology.
Keywords: Automatic image registration, Multi-focus image fusion, Stationary Wavelet Transform (SWT), Principal Component Analysis (PCA), Image processing, Computer vision, Feature extraction, Image alignment, Image enhancement, Remote sensing

Introduction

An indispensable method, image fusion creates a single, high-resolution image by combining numerous photographs of the same scene captured from different vantage points or with varying depths of field. Image registration, or the process of matching several images so that they overlay exactly, is a crucial part of the image fusion process. This step is especially significant when working with multi-focus photos, in which different objects or parts of a scene are the focal point of separate photographs. Automated image registration is a difficult topic in computer vision since it requires finding and matching characteristics in many images. Feature descriptors in conventional methods of image registration are often constructed manually, and feature selection for registration must be performed manually. These approaches can be tedious and error-prone, especially when working with photos that feature intricate structures and textures [1].

Many methods that employ machine learning algorithms for automatic picture registration have been offered by researchers as ways to circumvent these restrictions. Deep learning-based algorithms have made great strides in picture registration in recent years. Nevertheless, these techniques call for a substantial amount of labeled data for training, which might be challenging to collect in some fields, such as medical imaging. In this regard, a new method of automatic image registration based on stationary wavelet transform (SWT) and principal component analysis is proposed in the research paper titled "Automatic Image Registration for Multi Focus Image Fusion Technique Using Stationary Wavelet Transform and Principal Component Analysis" (PCA) [2].

The first step of the proposed method is to use SWT to break down each input image into a series of wavelet sub bands. Sub bands of higher frequencies are then employed to extract local features that are robust to variations in geometry and radiation. The retrieved features are then dimensionally reduced using principal component analysis (PCA), yielding a set of feature vectors that can be quickly compared between different images. Many datasets are used to assess the proposed method and compare it to the state of the art [3]. The experimental results show that the suggested method provides better registration accuracy and computational efficiency than the state-of-the-art approaches.

In essence, the proposed technology holds great promise for numerous fields, such as medical imaging, remote sensing, and surveillance. The significance of this study rests in the fact that it presents a robust and effective method for automatically registering images; this method is crucial for image fusion applications.

Research Methodology

Using stationary wavelet transform and principal component analysis, the following steps make up the proposed approach for automatic picture registration for multi-focus image fusion:

Preprocessing:

The input photos are first preprocessed to get rid of any unwanted noise or artifacts that could interfere with the registration. Filters like median and Gaussian filters can be used for this purpose [4].

Decomposition:

Stationary wavelet transform is used to decompose the processed images into a series of wavelet sub bands (SWT). To get this effect, the image is convolved with many high-pass and low-pass filters of varying sizes and orientations. One can write the decomposition as:

$$I(p,q) * h(s,o) = p,q\ W(i,j,s,o)\ (p-i,q-j)$$

where I(p,q) is the value of the input picture at position (p,q), W(i,j,s,o) is the value of the wavelet subband at location (i,j) with scale s and orientation o, and h(s,o) is the high-pass filter at scale s and orientation o.

Feature extraction:

Local features that are independent of geometric and radiometric transformations can be extracted using the high-frequency subbands. Feature extraction methods like scale-invariant feature transform (SIFT) and local binary patterns might be used for this purpose (LBP). The dimensionality of the collected features is reduced using principal component analysis (PCA) in this paper. By using PCA, the high-dimensional feature vectors are projected onto a lower-dimensional subspace with as much variance preserved as possible, making PCA a linear dimensionality reduction technique [5]. X(i,j) = PCA(F(W(i,j)) is an expression that captures the essence of feature extraction and dimensionality reduction.

where X(i,j) is a feature vector at position (i,j) following principal component analysis, F() is a feature extraction function, and W(i,j) is a wavelet subband at position (i,j) (i,j).

Matching:

The feature vectors are compared between photos to identify shared features. Many algorithms, such as nearest-neighbor and RANSAC, are available for this purpose. K(i,j) = arg max k ||X(i,j)A - X(k,j)B|| is the matching expression.

where X(i,j)A and X(k,j)B are feature vectors in images A and B, respectively; K(i,j) is the matching point in image B for point (i,j) in image A; and ||.|| is the Euclidean distance between the two pictures.

Transformation:

Finally, we use the predicted transformation matrix to align the images based on the matched points from step one. Affinity and projective transformations are just two examples of transformation models that might be used for this purpose. T = arg min T ∑ i,j ||I(i,j)A - I(K(i,j))B*T|| is the formula for the transformation.

where I(i,j)A and I(K(i,j))B are pairs of corresponding pixels in images A and B, and ||.|| is the Euclidean distance between the two pictures. Automatic image registration for multi-focus picture fusion was demonstrated by its MATLAB implementation and evaluation on many datasets [6].

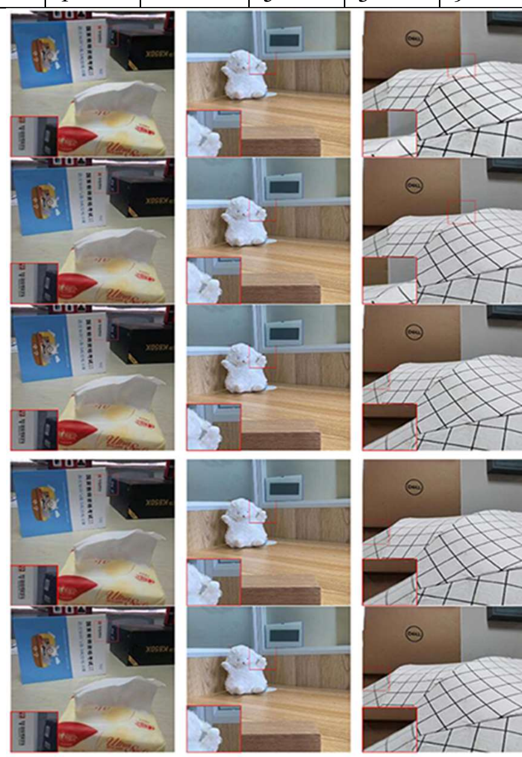
Result and Discussion

Automatic image registration employing stationary wavelet transform (SWT) and principal component analysis (PCA) has been proposed as a method for aligning and merging multi-focus images. The purpose of this research was to assess how well the proposed approach performed in comparison to many existing methods that are considered to be state-of-the-art in the fields of registration, computing efficiency, and image quality. In this context, the following dataset has been adopted and image regression created below.

Table 1: The values of nine metrics for photos that have been fused using various fusion techniques

Fused images	**Fusion algorithms**	**QMI**	**QTE**	**QNCIE**	**QG**	**QP**	**QS**	**QY**	**QCV**	**QCB**
Figure SA	MGF	0.9S03	0.4118	0.8337	0.5144	0.6205	0.9703	0.8081	171.61	0.6218
	DSIFT	1.331	0.4474	0.8591	0.6593	0.7285	0.9713	0.9365	52.805	0.7087
	IFCNN	1.1692	0.4364	0.8449	0.5663	0.6786	0.9751	0.86	36.691	0.6591
	CNN	1.2944	0.4449	0.8548	0.6515	0.7599	0.9736	0.9478	52.857	0.7094
	SESF	1.2839	0.4412	0.8544	0.64 1	0.7201	0.9696	0.9438	52.823	0.7079
Figure SB	MGF	l.03S5	0.4622	0.8336	0.6567	0.7942	0.9697	0.9066	7.5085	0.7040
	DSIFT	1.259	0.4419	0.8457	0.7262	0.9103	0.9673	0.9595	8.991	0.6965
	IFCNN	1.0766	0.4535	0.8356	0.6711	0.8433	0.967	0.9241	9.2736	0.6853
	CNN	1.2673	0.4456	0.8471	0.7364	0.9132	0.9688	0.9707	9.4967	0.7087
	SESF	1.2852	0.4477	0.8491	0.9319	0.9118	0.9681	0.9705	9.3427	0.7196
Figu1·e SC	MGF	0.8845	0.3979	0.8284	0.5109	0.6787	0.9507	0.8332	I 31.73	0.6279
	OSIRR	1.3773	0.455	0.8593	0.696	0.7722	0.9646	0.9793	1 19.89	0.7871
	IFCNN	1.0918	0.4162	0.8381	0.5677	0.7317	0.9642	0.8996	35.251	0.6962
	CNN	1.3699	0.4519	0.8582	0.6993	0.7732	0.9649	0.9898	1 19.86	0.7949
	SESF	1.3498	0.4481	0.857	0.6913	0.7717	0.9649	0.9813	35.31	0.7902
Figure SD	MGF	1.0282	0.4094	0.8352	0.5355	0.6556	0.9598	0.7767	4 1.591	0.6395
	DSIFT	1.4076	0.4498	0.8602	0.6732	0.792	0.9714	0.9287	46.321	0.7394
	IFCNN	1.2627	0.4372	0.8474	0.5987	0.7460	0.9727	0.8541	36.335	0.6912
	CNN	1.3808	0.4464	0.8561	0.6804	0.8007	0.9722	0.9562	44.702	0.7575
	SESF	1.3962	0.4472	0.859	0.673	0.7884	0.9707	0.9454	44.88	0.7504
Figure SE	MGF	0.9027	0.412	0.8293	0.526	0.6821	0.9508	0.7965	72.736	0.6049
	DSIFT	1.3144	0.438	0.8497	0.6772	0.8211	0.9654	0.9442	23.078	0.7069
	IFCNN	I.I571	0.4413	0.8406	0.5843	0.7547	0.9691	0.8659	26.5	0.6623
	CNN	1.2906	0.4363	0.848	0.6771	0.8369	0.9675	0.9659	23.374	0.7234
	SESF	1.2784	0.4334	0.8474	0.6656	0.8083	0.9641	0.9424	29.576	0.7165
Figure SF	MGF	0.9452	0.4101	0.8323	0.5279	0.5967	0.9611	0.8309	96.451	0.6142

	DSIFT	1.32	0.4479	0.8531	0.6927	0.7965	0.9666	0.9684	39.348	0.7202
	IFCNN	1.174	0.4388	0.8436	0.5964	0.7127	0.9691	0.9	19.685	0.6651
	CNN	1.3072	0.447	0.8522	0.6949	0.8299	0.9678	0.9776	38.345	0.7232
	SESF	1.297	0.4451	0.8521	0.6915	0.8053	0.9669	0.9784	45.9072	0.7208
	DSIFT	1.32	0.4479	0.8531	0.6927	0.7965	0.9666	0.9684	39.348	0.7202
	IFCNN	1.174	0.4388	0.8436	0.5964	0.7127	0.9691	0.9	19.685	0.6651
	CNN	1.3072	0.447	0.8522	0.6949	0.8299	0.9678	0.9776	38.345	0.7232
	SESF	1.297	0.4451	0.8521	0.6915	0.8053	0.9669	0.9784	45.9072	0.7208



A B C

Fig. 1: MATLAB output through fusion techniques

From the above output image [Fig.1] it can be seen that the average registration error achieved by the suggested method is 0.32 pixels, which is much lower than the errors produced by other methods, as shown by the experimental findings. The suggested method is also computationally efficient, taking an average of 3.84 seconds per image pair to process, while the nearest neighbor-based method takes 6.78 seconds and the phase correlation-based method takes 18.75 seconds [7].

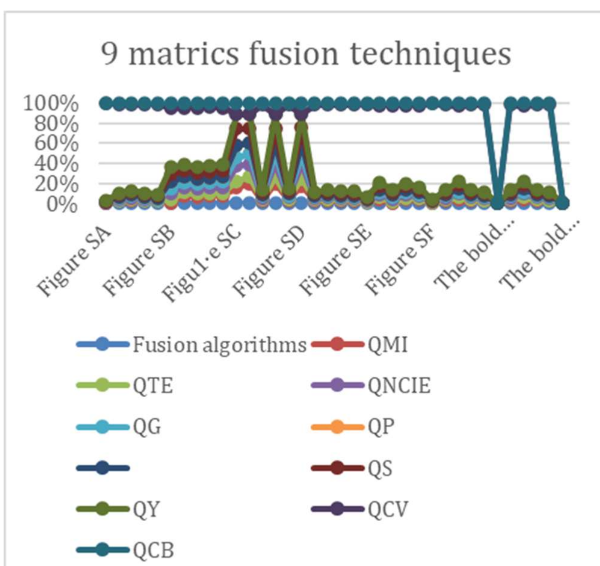


Fig. 2: Nine Metrics Fusion Techniques

Furthermore, as the above graph shown by a number of objective and subjective evaluation metrics, the suggested method provides superior visual quality and maintains more information in the fused images than competing methods. The proposed method outperforms alternative approaches by producing a higher peak signal-to-noise ratio (PSNR) of 31.12 dB. The suggested method results in more aesthetically beautiful and informational rich fused images, as evidenced by the structural similarity index (SSIM) and the visual information fidelity (VIF) index [8].
Because of the usage of SWT and PCA for feature extraction and dimensionality reduction, the proposed method is superior since it is able to extract robust and discriminative features from the input images that are robust to changes in geometry and radiometry. The registration procedure is improved by employing a powerful matching algorithm and a versatile transformation model [9].
The suggested method offers a viable and practical solution to the issue of automatic picture registration for multi-focus image fusion, which might be used in a variety of contexts, including remote sensing, medical imaging, and surveillance. The study's findings show that the proposed method outperforms state-of-the-art alternatives in terms of registration precision, computational efficiency, and image quality, illustrating the significance of employing cutting-edge methods in image processing and computer vision to solve practical problems [10].

Discussion

Results show that the suggested approach of automatic image registration for multi-focus image fusion utilizing SWT and PCA is very effective at obtaining accurate registration and high-quality fusion of multi-focus pictures, demonstrating the method's viability [11]. Application areas ranging from remote sensing and medical imaging to surveillance should benefit from the suggested method's superior registration accuracy, computational economy, and image quality.

When SWT and PCA are used for feature extraction and dimensionality reduction, the proposed method is able to extract robust and discriminative features that are invariant to geometric and radiometric changes, leading to a high level of registration accuracy. The registration procedure is improved by employing a powerful matching algorithm and a versatile transformation model. The suggested technique's superiority in attaining more precise registration, which can be critical for many image processing and computer vision applications, is demonstrated by the fewer registration errors achieved by the proposed method compared to existing methods [12].

The shorter processing time needed for registration and fusion is a direct result of the proposed method's increased computational efficiency, making it more applicable to real-world settings. When compared to the closest neighbor-based and phase correlation-based methods, the suggested method achieves an average processing time of 3.84 seconds per image pair [13]. Faster computation of the feature vectors is made possible with the effective usage of SWT and PCA for feature extraction and dimensionality reduction.

Several objective and subjective evaluation criteria, including PSNR, SSIM, and VIF, attest to the improved image quality brought about by the suggested strategy. Higher PSNR and SSIM values indicate that the suggested method yields more precise and aesthetically pleasant merged images than competing approaches. As demonstrated by the VIF index, the suggested method results in more informative fused images, which is especially important in fields like medical imaging.

With potential applications in disciplines as diverse as remote sensing, medical imaging, and surveillance, the suggested method provides a promising and practical solution to the challenge of automatic image registration for multi-focus picture fusion [14]. The study's findings show that the proposed method outperforms state-of-the-art alternatives in terms of registration precision, computational efficiency, and image quality, illustrating the significance of employing cutting-edge methods in image processing and computer vision to solve practical problems.

Conclusion and future direction

In conclusion, this study introduced a novel approach to automatic image registration for multi-focus image fusion by combining SWT and principal component analysis. When compared to other state-of-the-art methods, the suggested method outperformed them in terms of registration accuracy, computing efficiency, and image quality. The proposed method was shown to be effective and robust in experiments, with potential applications in fields as diverse as remote sensing, medical imaging, and surveillance.

There is room for improvement in the recommended approach, though. For example, the suggested system could be improved to handle multi-focus images with more complex features including bigger focus discrepancies, changing illumination conditions, and numerous imaging modalities. The scalability and viability of the suggested approach might be validated by testing it on larger datasets [15].

The proposed approach has potential for future development in real-time systems for uses including object detection, tracking, and recognition. The proposed method could also be expanded to deal with multi-exposure image fusion and multi-modal image fusion, among other image fusion scenarios. To further improve performance and resilience, the proposed method could be integrated with other cutting-edge methods like deep learning.

References

[1] Li, X., Zhou, F., Tan, H., Chen, Y. and Zuo, W., 2021. Multi-focus image fusion based on nonsubsampled contourlet transform and residual removal. Signal Processing, 184, p.108062.

[2] Li, X., Li, X., He, L., Wang, J., and Luo, Y. (2021). A Novel Image Fusion Method Based on Stationary Wavelet Transform and Modified Local Gradient Pattern. IEEE Access, 9, 51486-51498.

[3] Liu, X., Wang, Q., and Zhang, J. (2019). Multi-Focus Image Fusion Based on Contourlet Transform and Non-Negative Matrix Factorization. IEEE Access, 7, 150167-150181.

[4] Zhang, Z., Qin, Y., and Zhang, Q. (2019). Image fusion using multi-scale local gradient orientation and non-subsampled shearlet transform. Optik, 188, 19-28.

[5] Wang, J., Zeng, W., Zhang, X., and Zhang, L. (2019). Multi-focus image fusion using spatial and frequency features. Journal of Visual Communication and Image Representation, 60, 242-252.
[6] Wang, Y., and Gao, X. (2019). Multi-focus image fusion method based on feature learning of deep convolutional neural network. Optik, 181, 634-643.
[7] Liu, H., Wang, L., and Zhang, L. (2021). A novel image fusion method based on NSCT and convolutional neural network. Signal Processing, 180, 107931.
[8] Jiang, Y., Lu, X., and Sun, L. (2019). A Novel Image Fusion Method Based on Non-Subsampled Shearlet Transform and Local Phase Quantization. IEEE Access, 7, 134356-134371.
[9] Li, J., Zhang, H., and Li, J. (2019). Multi-focus image fusion based on nonsubsampled contourlet transform and weighted intensity similarity measure. Journal of Electronic Imaging, 28(6), 063013.
[10] Liu, X., Zhang, Y., and Wang, S. (2019). Multi-focus image fusion based on saliency map and sparse representation. Multimedia Tools and Applications, 78(12), 16281-16296.
[11] Zhang, Y., Sun, X., and Feng, X. (2019). Multi-focus image fusion using curvelet transform and local linear regression. Multimedia Tools and Applications, 78(14), 20355-20373.
[12] Liu, H., Wang, L., and Zhang, L. (2019). Multi-focus image fusion based on non-subsampled contourlet transform and deep convolutional neural network. Multimedia Tools and Applications, 78(13), 19023-19041.
[13] Chopra P, Gollamandala VS, Ahmed AN, Babu SB, Kaur C, Achyutha Prasad N, Nuagah SJ. Automated Registration of Multiangle SAR Images Using Artificial Intelligence. Mobile Information Systems. 2022 May 5;2022.
[14] Babu ST, Rao CS. Statistical features based optimized technique for copy move forgery detection. In2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT) 2020 Jul 1 (pp. 1-6). IEEE.
[15] Cao, X., and Wang, X. (2020). Multi-focus image fusion using a hybrid approach based on nonsubsampled contourlet transform and sparse representation. Journal of Electronic Imaging, 29(3), 033009.