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THE ROLE OF MATLAB APPLICATION FOR VISUALIZING MRI IMAGES OF THE TRIGEMINAL NERVE WITH FUSION TECHNIQUE

Dr. Sudiyono, SE, M.Kes[1],Dr. Sugiyanto, S.Pd, M.App.Sc[2],Mega Indah Puspita, S.ST, M.Kes[3]
[1-3]Poltekkes Kemenkes Semarang, Indonesia

Mega Indah Puspita, S.ST, M.Kes
Email: megaindahpuspitaa@gmail.com

ABSTRACT

This study addresses the crucial role of Magnetic Resonance Imaging (MRI) of the head in detecting disorders of the trigeminal nerve, particularly trigeminal neuralgia. Trigeminal neuralgia can significantly affect quality of life and is commonly observed in the elderly. However, some hospitals face limitations due to the absence of image fusion features in their MRI modalities, highlighting the need for practical alternative solutions.

This study proposes the development of a MATLAB-based image fusion application as a practical alternative. The use of this application is expected to enhance visualization of the trigeminal nerve and surrounding blood vessels, particularly in hospitals whose MRI devices lack integrated image fusion capabilities. A mixed-methods approach was employed, combining qualitative analysis to describe the process of implementing image fusion using MATLAB, and quantitative analysis to compare the results with those from built-in fusion software on MRI machines.

This study successfully implemented image fusion techniques using MATLAB on raw data obtained from CISS 3D and 3D TOF sequences, with a focus on visualizing the trigeminal nerve. The comparison between the fused images generated using MATLAB and those produced by the MRI system's built-in fusion software revealed significant differences. The MATLAB-based image fusion technique demonstrated a substantial contribution to improved understanding and diagnosis in medical practice, particularly in merging images from different MRI modalities. Thus, MATLAB-based fusion can be considered a relevant and progressive solution, especially for hospitals lacking access to advanced fusion technology.

Keywords: Trigeminal Nerve, Trigeminal neuralgia, Image Fusion, MATLAB Application

Introduction

Magnetic Resonance Imaging (MRI) uses strong magnetic fields and radio waves to produce high-resolution images of structures and organs. Its capability to detect potentially serious or fatal injuries makes MRI a highly reliable diagnostic modality. In a diagnostic context, head MRI plays an essential role in detecting various brain abnormalities such as stroke, infections, tumors, vascular disorders, and provides detailed visualization of cranial nerves, including the trigeminal nerve. The trigeminal nerve, being the largest cranial nerve, has an extensive sensory function in the head and neck and also acts as a motor nerve for the muscles involved in mastication. Disorders of the trigeminal nerve may result in symptoms such as stabbing facial pain, facial paralysis, and involuntary movements. Trigeminal neuralgia, one such disorder, is often caused by pulsatile vascular compression of the trigeminal nerve, leading to stabbing sensations in various areas of the face. Cases of trigeminal neuralgia generally occur in individuals over 40 years of age, with the highest prevalence between 60 and 70 years, largely due to atherosclerotic changes in blood vessels near the trigeminal nerve. Although not life-threatening, trigeminal neuralgia significantly affects quality of life, limiting daily activities and potentially leading to depression.

The trigeminal nerve has gained attention in Indonesia's healthcare transformation, particularly within the Ministry of Health's Referral Service Transformation Pillar, which aims to equalize referral services by optimizing the national hospital network. The prevalence of trigeminal neuralgia is estimated at 0.16%–0.3%, with incidence rates ranging from 4 to 29 per 100,000 people per year. Recent studies have also reported trigeminal neuralgia in younger individuals, between 9.5 and 16.5 years of age. Moreover, patients with hypertension are reported to have a higher incidence of trigeminal neuralgia compared to the general population. Among brain imaging modalities, the sequences commonly used in MRI examinations to visualize the trigeminal nerve include Sagittal SE T1/coherent T2*, Axial SE/FSE T1, Axial SE/FSE with contrast, Coronal SE/FSE T1 with/without contrast, 3D incoherent (spoiled) GRE T1 with/without contrast, Axial FSE T2, and Coronal FSE T2. In addition, specialized high-resolution sequences such as 3D FSE T2 (SPACE) and 3D GRE T2 (CISS) are used for detailed visualization of the trigeminal nerve.

The advancement of medical technology, particularly in radiology, has seen rapid growth in recent years. Radiologists now have access to advanced diagnostic methods such as MRI with 3D CISS sequences and 3D TOF MRA. However, the increasing demand for precise and complex diagnoses drives continuous development and refinement of imaging techniques.

Unfortunately, some hospitals still face limitations in providing image fusion features, especially those using older MRI systems. Image fusion has become increasingly necessary due to its importance in establishing accurate diagnoses. This is evident in the distinct differences in visualization of the trigeminal nerve and surrounding vessels between CISS 3D and TOF 3D sequences. With technological advancements, radiologists must stay updated to provide optimal diagnostic services. Yet, some hospitals are constrained by older MRI systems that lack built-in image fusion software. In this context, the development of a MATLAB-based image fusion application becomes highly relevant. The lack of access to image fusion software in certain hospitals may create disparities in diagnostic capabilities. Therefore, this research proposes a practical solution through the development of a MATLAB-based application. This application is expected to assist radiologists, radiographers, and clinical doctors in enhancing visualization of the trigeminal nerve and adjacent blood vessels without relying on native image fusion features of MRI systems.

The existence of this image fusion application is expected to offer a viable solution for hospitals that do not have access to the latest technologies. By utilizing MATLAB-based software, this application simplifies the evaluation of the trigeminal nerve and allows for more accurate detection of abnormalities. Thus, amid rapid advancements in medical technology, this application represents a progressive step to meet the needs of healthcare institutions that may lag in implementing image fusion features in their MRI systems.

Methods

This study was conducted with the primary objective of implementing image fusion techniques using a MATLAB-based application on raw data from 3D CISS and 3D TOF sequences, with a specific focus on the visualization of the trigeminal nerve. The critical stages of the research involved image acquisition, image preprocessing to ensure optimal quality before fusion, and the application of fusion methods using MATLAB. The results from this fusion technique were then compared with the outcomes produced by the built-in fusion software on the MRI system, which served as the golden standard.

The research design adopted a mixed-methods approach, incorporating a qualitative method to describe the process of applying the MATLAB-based fusion technique on raw 3D CISS and 3D TOF data, and a quantitative method to compare the results of the Matlab fusion application with the MRI software fusion.

The tools used in this study included an MRI Aera system from Siemens AG (2012) and a computer running MATLAB R2018b. MRI examinations were conducted using 3D CISS and 3D TOF MRA sequences. The images were read and fused by adjusting grayscale intensity values. A visual assessment was carried out by a radiologist to evaluate the clarity of anatomical information regarding the trigeminal nerve and surrounding blood vessels. This methodology is expected to provide a comprehensive understanding of the process and outcomes of the image fusion technique, as well as objectively measure the level of accuracy and advantages of the MATLAB-based application compared to the built-in fusion software on the MRI system.

Results and Discussion

This study successfully achieved its objective by implementing an image fusion technique using a MATLAB-based application on raw data from 3D CISS and 3D TOF sequences, with a primary focus on visualizing the trigeminal nerve. The research process involved several critical stages, including image acquisition, preprocessing to ensure optimal quality prior to fusion, and the application of the fusion method using MATLAB. The outcomes of this fusion technique were compared with the results obtained from the built-in MRI fusion software, which served as the reference standard.

The study employed a mixed-method approach, utilizing qualitative methods to describe the application process of the image fusion technique using MATLAB, and quantitative methods to compare the fusion results between MATLAB and the MRI software. The tools used included an MRI Aera system from Siemens AG (2012) and a computer using MATLAB R2018b programming language. MRI examinations were performed using 3D CISS and 3D TOF MRA sequences.

The image fusion process on the MRI system was carried out using the built-in fusion feature of the Siemens platform, which provided clear and accurate visualization of the trigeminal nerve. The application of this fusion technique enhanced diagnostic capabilities for evaluating conditions and abnormalities related to the trigeminal nerve at the neurovascular level.

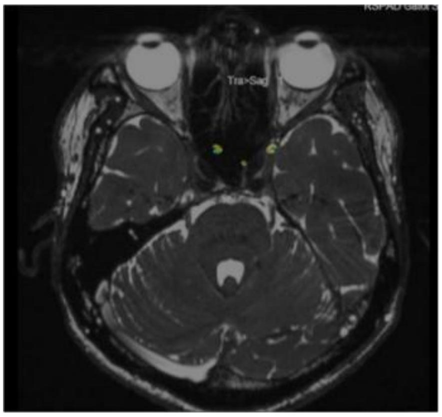

Figure 1. MRI Modality Fusion Results

In the next stage, the implementation of image fusion techniques with MATLAB involves detailed steps, such as using the DWT and PCA algorithms. The Diagnostic Imaging IT Team successfully compiled the MATLAB code with a structured structure and tested its functionality, including the design of the user interface (GUI) display to facilitate operation.

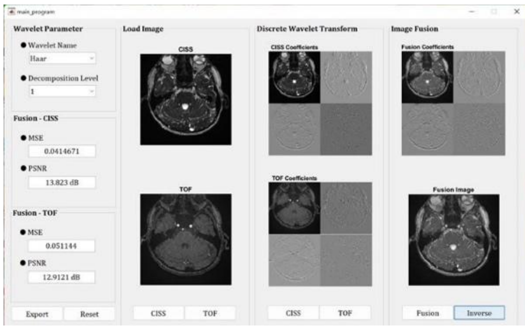

Figure 2. GUI View In MATLAB

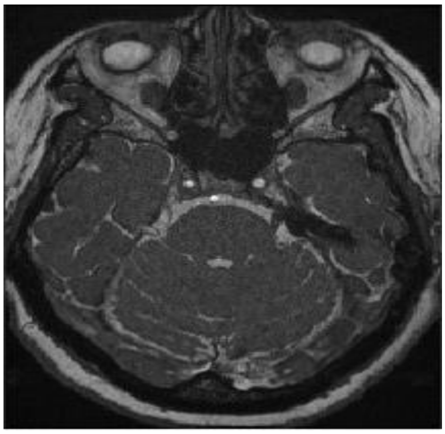

Figure 3. Fusion Image Merging Results Using MATLAB

The image results from both fusion techniques, both from MRI and MATLAB devices, were assessed by three Radiology Specialists with more than 5 years of experience through a questionnaire. Statistical analysis using the Wilcoxon test showed a significant difference between the results of MATLAB image fusion and MRI modality image fusion (p-value = 0.021).

Table 1. Results Of The Wilcoxon Difference Test

Variable	p-value	Information
Fusi MRI and Fusi Matlab	0,020	There is a difference

The interpretation of the results indicates that the image fusion method using MATLAB yields significantly different outcomes compared to image fusion using the built-in MRI system. This finding provides a foundation for further development or refinement of image fusion methods, with the aim of enhancing the quality and accuracy of fused images in medical applications. The results suggest that image fusion using MATLAB can serve as an effective alternative for producing high-quality visualizations of the trigeminal nerve, enriching diagnostic information. Thus, this study offers a valuable contribution to the advancement of diagnostic technology in radiology, particularly in the context of trigeminal nerve visualization and evaluation.

The Wilcoxon non-parametric test in this study provided statistically significant evidence regarding differences between fused images from the MRI modality and those generated using the MATLAB application. With a p-value of 0.021, which is smaller than the predetermined significance level of 0.05, it can be concluded that there is a meaningful difference between the two image sets. This result establishes a solid basis for discussing the implications and relevance of these findings in clinical practice, especially in medical image interpretation and diagnosis.

The fact that the MATLAB-based image fusion method produced significantly different outcomes from those of the MRI modality is an intriguing finding that warrants further elaboration. Interpreting this difference provides valuable insight into the effectiveness and accuracy of the fusion technique used in this study. In the medical field, where visual information accuracy is critical, these findings are essential for MRI practitioners in choosing the most appropriate fusion method for their diagnostic needs. According to Guo et al. (2022), medical image fusion plays a central role in supporting clinical diagnosis. Their study explores the concept of merging medical images such as CT and MRI to provide a more comprehensive view. Fusion integrates information from different image modalities, for example, CT highlights bone structures while MRI focuses on soft tissue. The main advantages of image fusion include lesion detection, tumor growth monitoring, high-resolution processing through multiscale decomposition, and the selection of optimal fusion strategies for various image components. Beyond visual enhancement, medical image fusion aims to improve diagnostic precision and consistency as well as treatment planning by offering richer and more valuable structural information for healthcare professionals.

The importance of MATLAB-based image fusion can also be emphasized in contexts where hospitals or medical facilities possess MRI systems without built-in fusion features. Developing MATLAB-based fusion code becomes essential in such scenarios, as it provides an implementable solution and introduces image fusion capabilities to modalities that lack this feature. This can deliver substantial benefits to medical practitioners, allowing them to enhance diagnostic accuracy and clarity through better visualization of anatomical structures. According to Zhou et al. (2023), the development of deep learning-based image fusion methods offers superior advantages in feature extraction and representation, more flexible network architectures, and end-to-end fusion processes that reduce information loss.

The use of deep learning in medical image fusion is anticipated to surpass traditional methods. In healthcare settings with limited infrastructure, medical image fusion emerges as an effective solution. It helps physicians better understand image content, allowing for more accurate, faster, and comprehensive diagnosis and treatment. Overall, medical image fusion proves to be a valuable alternative for resource-constrained healthcare facilities, unlocking potential improvements in the quality of medical services.

MATLAB is also seen as a tool that supports accurate diagnosis by enhancing the visualization of anatomical structures. In the constantly evolving medical field, the ability to present optimal visual information can significantly contribute to treatment success and patient care. Therefore, the development and application of reliable image fusion methods using MATLAB are crucial in supporting medical practitioners in their efforts to achieve higher accuracy and precision in diagnosis and patient management.

According to Lu Tang et al. (2022), MATLAB, as a goal-oriented programming language, plays a central role in MRI diagnosis and medical image processing. MATLAB's interactive and dedicated environment is essential for numerical computation, programming, and visualization—especially in the implementation of Discrete Wavelet Transform (DWT) for medical imaging like MRI. Its capabilities allow for data visualization, signal plotting, and image fusion using various wavelet types. With matrix operations and built-in functions such as "dwt2" and "idwt2", MATLAB significantly contributes to medical image processing by enabling the selection of parameters such as wavelet types and fusion methods. Therefore, MATLAB stands out as a critical tool not only for analyzing medical images but also for enhancing understanding and improving diagnostic processes in the medical field.

Conclusion

This study concluded that the implementation of image fusion methods using the MATLAB application in the context of MRI modality produces significantly different results compared to image fusion performed directly through the MRI system. The Wilcoxon non-parametric test showed that this difference is statistically significant, with a p-value of 0.021, which is lower than the commonly accepted significance level of 0.05. These findings provide a solid foundation for discussing the implications and relevance of the results in medical practice, particularly in the diagnostic and interpretive processes of medical imaging. The results enhance the understanding of the effectiveness and accuracy of image fusion methods using the MATLAB application and serve as an important consideration for MRI practitioners in selecting the most appropriate fusion method for their diagnostic needs.

Moreover, the study highlights the importance of developing image fusion methods—especially through the MATLAB platform—to improve the quality and accuracy of fused images in clinical practice. This conclusion supports the notion that image fusion methods, particularly those based on deep learning, have the potential to become a superior alternative to traditional techniques, offering opportunities to enhance services in healthcare facilities with limited resources. In general, this research not only contributes to a deeper understanding of image fusion methods in medical imaging diagnostics but also emphasizes the crucial role of the MATLAB application in supporting MRI diagnostic processes and medical image processing. This conclusion may serve as a basis for further development in technologies and methods within the field of medical imaging diagnostics, with the hope of making a tangible contribution to improving the quality of healthcare services.

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