Biomedical & Pharmacology Journal, March 2025. Vol. **18**(Spl.), p. 347-351

Special Issue – AI-Driven and Multimodal Innovations in Biomedical Imaging and Sensing

Editorial: AI-Driven and Multimodal Innovations in Biomedical Imaging and Sensing

Prabhishek Singh

School of Computer Science Engineering and Technology, Bennett University, Greater Noida, India.
*Corresponding author Email: prabhisheksingh88@gmail.com

https://dx.doi.org/10.13005/bpj/3092

(Received: 20 March 2025; accepted: 21 March 2025)

The special issue on "AI-Driven and Multimodal Innovations in Biomedical Imaging and Sensing" presents a collection of pioneering research articles that highlight the integration of artificial intelligence (AI) with various imaging modalities to enhance medical diagnostics, treatment planning, and healthcare monitoring. A central theme is the development of multimodal medical image fusion techniques utilizing deep learning and metaverse technologies, aiming to improve the assessment and treatment of patients by combining data from different imaging sources. Another significant contribution is a comprehensive overview of medical imaging techniques for diagnosing knee osteoarthritis, focusing on the application of AI to automatically detect and classify the disease from various medical images, including MRI, CT scans, and X-rays. Additionally, the issue explores the phenomenon of synchronization in EEG signals and its application in detecting neurological disorders, discussing how AI can assist in analyzing these signals for early diagnosis and treatment. Collectively, these articles demonstrate the transformative potential of AI-driven, multimodal approaches in biomedical imaging and sensing, offering promising avenues for more accurate diagnoses, personalized treatments, and improved patient outcomes.

This review highlights the role of Industry 4.0 technologies like IoT, AI, and cloud computing in revolutionizing pharmaceutical manufacturing. It discusses challenges such as high costs, expertise requirements, and regulatory compliance. The study emphasizes the need for autonomous AI-driven systems to advance the pharmaceutical sector.[1] 3D printing has revolutionized pharmaceutical manufacturing by enabling cost-effective, on-demand production of complex and customized drug delivery systems. The technology offers significant advantages over traditional methods, including personalized dosages, intricate solid dosage forms, and improved production efficiency. However, regulatory, and technological challenges remain, necessitating further advancements to fully integrate 3D printing into routine pharmaceutical applications.[2] Authors explain that digital dermoscopy is a non-invasive imaging technique that enhances skin lesion assessment by providing high-resolution images for early diagnosis of melanoma, basal cell carcinoma, and squamous cell carcinoma. They highlight how AI integration has improved diagnostic accuracy but acknowledge challenges related to image quality, clinician expertise, and integration with electronic health records and telemedicine systems.[3] This study explores the application of machine learning techniques, including Support

Vector Machines (SVM), Random Forests (RF), and deep learning models like VGG16 CNN, to enhance the accuracy of kidney stone detection. The findings highlight VGG16's effectiveness in feature extraction and classification while addressing challenges in data accessibility, model transparency, and clinical integration. [4] Authors of this study explore the potential of self-supervised learning in digital pathology to address the challenge of limited labeled data, enabling efficient disease detection and classification from unannotated pathology images. The study highlights advanced techniques like contrastive learning and longitudinal self-supervised learning, demonstrating their effectiveness in extracting meaningful features and bridging the gap between digital pathology and machine learning.[5] The study evaluates the Adaptive Moving Self-Organizing Map (AMSOM) for brain tumor segmentation in MRI images, demonstrating its superior performance over FCM, FKM, and SOM-FKM in terms of accuracy, PSNR, and MSE. AMSOM achieved 89.11% accuracy and 96.8% similarity, highlighting its effectiveness for precise and efficient tumor detection in medical imaging applications.[6]

The study evaluates the Adaptive Moving Self-Organizing Map (AMSOM) for brain tumor detection in MRI images, demonstrating its superior segmentation accuracy over traditional clustering methods like FCM and FKM. With an MSE of 0.01, PSNR of 68.16 dB, and accuracy of 89.11%, AMSOM proves to be a highly effective approach for medical imaging applications.[7] The study presents a hybrid deep-learning model combining Vision Transformer (ViT) and Capsule Network (CapsNet) to enhance brain tumor classification and segmentation accuracy in MRI scans. Utilizing the BRATS2020 dataset, the model achieves 90% accuracy, outperforming traditional methods and demonstrating improved sensitivity and specificity in tumor detection.[8] The authors propose a new combined approach for identifying potential areas of interest in cytological images using edge detection operators, demonstrating its effectiveness compared to classical methods. The results show improved image quality assessments, achieving at least 10% superiority in NIQE, over 20% in BRISQUE, and enhanced detail analysis, leading to more efficient clinical decision-making.[9] The proposed DnCNN model effectively denoises Gaussian noise in CT images, outperforming traditional filtering techniques by preserving finer anatomical details and enhancing diagnostic accuracy. Quantitative evaluations, including PSNR (35.66 dB), SNR (30.16 dB), SSIM (0.91), and ED (0.35), confirm its superior performance in medical image denoising.[10] Authors investigate the effectiveness of transfer learning in diagnosing Parkinson's disease using DaTscan images, leveraging pre-trained deep learning models for feature extraction. The study demonstrates that neural networks outperform other machine learning models, achieving an AUC of 0.996 and MCC of 0.946, highlighting their robustness in high-precision classification tasks.[11] Authors present a fuzzy set theoretic framework to enhance AI-driven medical imaging, addressing challenges of interpretability and domain shifts. Through a tumor classification case study, the approach demonstrates reliable pixel classification using fuzzy membership grades and weighted defuzzification, improving AI's trustworthiness in clinical applications.[12]

The proposed Ens-DRDF model integrates advanced machine learning and image processing techniques for the simultaneous detection of diabetic retinopathy and diabetic foot ulcers. By employing optic disc and blood vessel removal, feature extraction, segmentation, and fuzzy clustering, the model enhances lesion differentiation and improves diagnostic accuracy.[13] This study explores advancements in image segmentation and classification for osteoporosis detection using enhanced Pix2Pix and Vision Transformer (ViT) architectures. The refined Pix2Pix model achieves a specificity of 97.24%, while the modified ViT models, particularly MViT-B/16, attain 96.01% accuracy, highlighting their potential in precise and early diagnosis.[14] The authors present a deep learning-based approach for classifying and assessing the severity of Knee Osteoarthritis (KOA) using the publicly available OAI dataset. By leveraging the VGG-16 model for both binary and multi-class classification, the study achieves improved accuracy and efficiency over traditional diagnostic methods, reducing reliance on manual expertise.[15] Authors present a performance comparison of Neural Network (NN) classifiers using different activation functions for EMG-based DSPN classification on the ZCU102 FPGA board. Results highlight that ReLU-based NNs achieve 78% accuracy with optimal power efficiency, resource utilization, and processing speed, making them well-suited for edge-based biomedical applications.[16] Authors highlight the effectiveness of a multimodal approach for real-time stress monitoring by analyzing EEG and ECG signals, demonstrating that fusion-based models significantly improve accuracy. The study leverages the Archimedes Optimization Algorithm (AoA), Analytical Hierarchical Process (AHP), and a hybrid DCNN-LSTM model, positioning AI-driven systems as robust tools for early stress detection and mental health management.[17] Authors present a hybrid machine learning approach integrating mRMR-RSA for efficient feature selection in lung cancer classification using microarray gene expression data. The K-Nearest Neighbor (KNN) algorithm outperformed other models, achieving 92.37% accuracy on dataset1 and 92.01% on dataset2, demonstrating its potential for early and precise lung cancer detection, enabling personalized treatment strategies.[18]

Authors explain that noise and low resolution in DXA and X-ray images hinder osteoporosis diagnosis. A comparative analysis of anisotropic diffusion, multi-scale wavelet analysis, adaptive guided filtering, and neural network-based denoising reveals that the deep learning approach outperforms others, achieving superior noise reduction while preserving critical bone structures for enhanced diagnostic accuracy.[19] The authors discuss how artificial intelligence (AI) is revolutionizing personalized healthcare and precision medicine by enabling advanced disease prediction, tailored treatment strategies, and AI-driven drug discovery. The review highlights key AI applications in biomarker discovery, virtual drug screening, and pharmacogenomics while addressing challenges such as data privacy, algorithmic bias, and ethical considerations in clinical implementation.[20] Authors of this research demonstrate that machine learning significantly enhances asthma diagnosis by integrating environmental, physiological, and lifestyle factors. The study achieves a 99% prediction accuracy using Random Forest and XGBoost, highlighting AI's potential to improve diagnostic precision and timely medical intervention.[21] The proposed hybrid deep learning architecture for EMG-based gesture detection effectively addresses challenges like inter-subject variability, noise interference, and electrode misalignment by integrating CNNs, BiLSTMs, and channel attention mechanisms. Extensive evaluations on the NinaPro dataset demonstrate its superior accuracy of 96.45%, outperforming existing methods and showcasing its robustness for real-world applications in prosthetics, human-computer interaction, and rehabilitation systems.[22] The study examines the role of e-governance strategies in integrating the Internet of Medical Things (IOMT) and Artificial Intelligence/Machine Learning (AIML) applications into medical administration during the COVID-19 pandemic in the Indian Subcontinent. Through SPSS-based analysis of 433 employees in India's tourism sector, the findings highlight e-governance's significant impact on healthcare resilience, mitigating unemployment effects through parental involvement and enhanced digital healthcare accessibility.[23]

CONCLUSION

This special issue on "AI-Driven and Multimodal Innovations in Biomedical Imaging and Sensing" highlights the transformative potential of artificial intelligence in medical diagnostics and healthcare applications. The featured research explores deep learning-driven image fusion, AI-assisted disease detection, and metaverse-based medical imaging, demonstrating the growing role of intelligent systems in enhancing diagnostic accuracy and treatment planning. The integration of multimodal imaging, particularly in knee osteoarthritis detection and EEG-based neurological analysis, showcases AI's capability to refine medical assessments and improve patient care. These advancements pave the way for personalized medicine, predictive analytics, and real-time health monitoring. As AI continues to evolve, collaboration between researchers, healthcare professionals, and engineers will be essential in maximizing its impact. This special issue serves as a foundation for future research, emphasizing AI's crucial role in shaping the future of biomedical imaging, ensuring more efficient healthcare solutions and improved patient outcomes.

REFERENCES

1. Ale Y, Verma R, Nainwal N. Jakhmola V, Pant P. IoT in Revolutionizing the Pharmaceutical Sector: Applications and Challenges. *Biomed Pharmacol J* 2025;18(March Spl Edition).
2. Sautha V, Butola M, Chaudhary M, Kumar P, Jakhmola V, Dhyani S, Ansori A. N. M. Overview of 3d Printing Technology with Pharmaceutical Applications, Challenges and Future Aspects. *Biomed Pharmacol J* 2025;18(March Spl Edition).
3. Arige S, Atmakuri L. R, Shaik R, Gude M, Ghanta V. K. Alluri R. Digital Dermoscopy: Advancements in Skin Cancer Diagnosis and Monitoring. *Biomed Pharmacol J* 2025;18(March Spl Edition).
4. Verma S, Singh P. K, Kaur G, Vashistha A, Pansari S. Non-Invasive Kidney Stone Prediction using Machine Learning: An Extensive Review. *Biomed Pharmacol J* 2025;18(March Spl Edition).
5. Adem A. M, Kant R, Sonia S, Kumar K, Mittal V, Jain P, Joshi K. Exploring Self-Supervised Learning for Disease Detection and Classification in Digital Pathology: A Review. *Biomed Pharmacol J* 2025;18(March Spl Edition).
6. Kumar K, Suwalka I, Anandaram H, Joshi K. An Automatic Simulation of MRI using Adaptive Unsupervised Mapping. *Biomed Pharmacol J* 2025;18(March Spl Edition).
7. Lamba R, Rani P, Sachdeva R. K, Bathla P, Kumar K, Mittal V, Joshi K. An Optimized Predictive Machine Learning Model for Lung Cancer Diagnosis. *Biomed Pharmacol J* 2025;18(March Spl Edition).
8. Simran S, Mehta S, Kukreja V, Dogra A, Brar T. P. S. Hybrid ViT-CapsNet Framework for Brain Tumor Diagnosis Using Biomedical MRI. *Biomed Pharmacol J* 2025;18(March Spl Edition).
9. Babker A, Suliman R. S, Ghazwani A. A. M, AlHarbi W, Lyashenko V. Combined Use of Edge Selection Operators in Individual Color Channels for the Analysis of Cytological Images Presented in RGB Format. *Biomed Pharmacol J* 2025;18(March Spl Edition).
10. Katta S, Singh P, Garg D, Diwakar M. An Efficient Gaussian Noise Denoising in CT Images with Deep Convolutional Neural Networks. *Biomed Pharmacol J* 2025;18(March Spl Edition).
11. Pant J, Pant H. K, Pant V. K, Bhatt V, Singh D, Joshi K. Deep Learning-Based Feature Extraction and Machine Learning Models for Parkinson's Disease Prediction Using DaTscan Image. *Biomed Pharmacol J* 2025;18(March Spl Edition).
12. Singh R, Chaudhary A, Ray S. Decoding Challenges using Mathematics of Fuzzy Theory in Interpretability, Shifts, Adaptation and Trust. *Biomed Pharmacol J* 2025;18(March Spl Edition).
13. Mewada A, Maurya S. K, Ansari M. A. Seeing Beyond: Advanced Image and Thermal Analysis for Early Detection of Diabetic Retinopathy and Diabetes. *Biomed Pharmacol J* 2025;18(March Spl Edition).
14. Dodamani P. S, Palanisamy K, Danti A. Novel Approach for Osteoporosis Classification Using X-ray Images. *Biomed Pharmacol J* 2025;18(March Spl Edition).
15. Rani S, Memoria M, Joshi K, Lamba A. K. Automated Knee Osteoarthritis Classification from X-ray Images Using the VGG-16 Model. *Biomed Pharmacol J* 2025;18(March Spl Edition).
16. Pandey S. K, Srivastava G. Comparative Study of Hardware Footprints of Neural Network Activation Functions for EMG Based Diabetic Sensorimotor Polyneuropathy Severity Classifier. *Biomed Pharmacol J* 2025;18(March Spl Edition).
17. Patil S. A, Paithane A. N, AI-Driven Multimodal Stress Detection: A Comparative Study. *Biomed Pharmacol J* 2025;18(March Spl Edition).
18. Gulande P, Awale R, A Hybrid mRMR-RSA Feature Selection Approach for Lung Cancer Diagnosis Using Gene Expression Data. *Biomed Pharmacol J* 2025;18(March Spl Edition).
19. Ramamoorthy G, Subramanian A, Rajendran T, Mohamed P. B. Comparative Analysis of Image Denoising Techniques for Osteoporosis Detection Using DXA and X-ray Imaging. *Biomed Pharmacol J* 2025;18(March Spl Edition).
20. Ranjan S, Singh A, Yadav R. Artificial Intelligence in Precision Medicine and Patient-Specific Drug Design. *Biomed Pharmacol J* 2025;18(March Spl Edition).
21. Kotlia P, Pant J, Lohani M. C. Identifying Asthma Risk Factors and Developing Predictive Models for Early Intervention Using Machine Learning. *Biomed Pharmacol J* 2025;18(March Spl Edition).

22. Kishore T, Remabai S. S, Retnaswamy C, Paul E. S. Enhanced EMG-based Gesture Recognition using Hybrid CNN-BiLSTM Architecture with Channel Attention. *Biomed Pharmacol J* 2025;18(March Spl Edition).

23. Vishnoi S, Yadav S. L, Saini A. K, Vats P. Transforming Healthcare Delivery: Assessing the Role of E-Governance Strategies in IOMT and AIML-Based Medical System Administration during the Pandemic in the Indian Subcontinent. *Biomed Pharmacol J* 2025;18(March Spl Edition).