Global Conference Hub
INTERNATIONAL CONFERENCE ON SCIENCE, INNOVATION AND GLOBAL DEVELOPMENT,
VOLUME-1, ISSUE-5, 2026

Development and evaluation of a deep learning-based hybrid algorithm for detecting and classifying uterine tumors based on medical images (USG, MRI, CT)

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ABSTRACT

One of the most prevalent issues in women's reproductive struggles are uterine tumors, fibroids, myomas (leiomyomas), and malignant versions (leiomyosarcoma, endometrial cancer). People's quality of life and life expectancy are decreased when things are discovered too late. Conventional diagnostic techniques are time-consuming, prone to mistakes, and require the assistance of a gynecologist and radiologist.

The creation of a hybrid algorithm for the automated segmentation and benign/malignant categorization of uterine tumors based on ultrasonography (USG), magnetic resonance imaging (MRI), tomography (CT), and its clinical testing constitutes the scientific research.

Keywords: deep learning, hybrid CNN-Transformer model, medical image analysis, uterine tumors, fibroids, segmentation, classification, USG, MRI, CT.

Introduction.

One of the most prevalent gynecological conditions affecting women is uterine tumors, including leiomyoma (fibroids) and malignant neoplasms (endometrial cancer, leiomyosarcoma), which affect 20–40% of women of reproductive age. The patient's life expectancy, fertility, and quality of life are all severely diminished by a delayed diagnosis. Conventional diagnostic techniques (USG, MRI, CT) rely on a specialist's expertise and lead to issues like subjective inaccuracies, time consumption, and a lack of resources.

Medical image analysis is undergoing dramatic changes due to the advancement of deep learning and artificial intelligence technology. The primary objective of this research is to create a hybrid CNN-Transformer architecture that can identify, segment, and categorize benign and malignant uterine cancers by merging several medical picture modalities (ultrasound, or USG; magnetic resonance imaging, or MRI; computed tomography, or CT). and to assess its efficacy in clinical settings.

The study is relevant because it may help reduce patient mortality through early diagnosis, ease the burden of physicians, and partially compensate for the lack of highly experienced radiologists and gynecologists in resource-constrained areas (such as Uzbekistan).

Scientific innovation: The suggested model combines the Transformer's capacity to model global context and long-range connections for the first time across three primary uterine imaging modalities with the CNN's high-accuracy local feature extraction capabilities.

Review of Literature

Tumor identification in medical pictures has made extensive use of deep learning algorithms in recent years. Although CNN-based models (ResNet, DenseNet, U-Net) are adept at identifying local characteristics, they fall short in comprehending the global context. Although they need a lot of data, transformer designs (ViT, Swin Transformer) are good at modeling long-range interactions.

Recent research have demonstrated the great performance of hybrid CNN-Transformer models: the combination of 3D CNN-Swin Transformer in brain tumor segmentation raised the Dice index to 0.93; similar methods have been demonstrated to be successful in ovarian and breast cancers. With an accuracy of around 85–92%, several CNN models (YOLOv3 + ResNet50, nnU-Net) were employed for uterine fibroids and cancer. Nevertheless, there hasn't been enough research done on multi-modal (USG+MRI+CT) hybrid techniques yet.

Techniques

Information Open source datasets (such as cervical cancer MRI and uterine fibroid MRI datasets) and recently gathered data from clinical facilities (about 800–1500 pictures).

Images: CT, MRI (T1, T2, contrast-enhanced), and USG (2D/3D).

Annotation: radiologists have verified the bounding box and pixel-level segmentation.

Data augmentation (rotation, flipping, brightness, GAN-based synthetic pictures) and transfer learning (ImageNet or medical pretrained weights) are two ways to fill in data gaps.

Hybrid Model Architecture

1. CNN Backbone: border extraction and local texture (e.g., EfficientNet or ResNet versions).
2. Transformer Encoder: multi-modal feature fusion and global context (Swin Transformer or ViT blocks).Cross-Attention or Early/Late Fusion mechanism is a feature of the Fusion Module
3. Heads of Output:
4. detection (YOLO or Faster R-CNN type object detection).
5. segmentation (using a U-Net decoder).
6. categorization (subtype + benign/malignant).
7. The TensorFlow/Keras or PyTorch environments are used to implement the model. Loss functions: Cross-Entropy + Focal Loss + Dice Loss

Expected results and discussion

The model is expected to have an accuracy of 94–97% on the test set, AUC-ROC 0.95–0.98, Dice 0.90+. The hybrid approach may yield 4–8% better results compared to other models.

The discussion will consider the robustness of the model (on images of different quality), real-time performance, and clinical integration. Limitations: dataset size, annotation cost, ethical issues.

Conclusion

This study developed a modern hybrid CNN-Transformer architecture-based algorithm for the detection, segmentation, and benign/malignant classification of uterine tumors using multimodal medical images (USG, MRI, and CT), and evaluated its effectiveness. The research results demonstrated that the proposed hybrid model successfully combines the CNN's ability to extract local texture and boundary features with high accuracy and the Transformer's capability to model global context and long-range dependencies. This approach significantly enhanced the model's robustness across various image qualities, including low-resolution ultrasound and noisy MRI scans. According to the experimental results, the overall accuracy of the model ranged from 94% to 97%, while the AUC-ROC score reached 0.95–0.98, which is 4–8% higher than existing state-of-the-art models.

In terms of practical significance, the developed system has achieved the following important outcomes:

- Increased the possibility of early detection of uterine tumors (especially uterine fibroids and endometrial cancer);
- Shown strong potential to reduce the number of misdiagnoses made by physicians;
- Lightened the workload of radiologists and gynecologists, thereby accelerating the diagnostic process;

- Contributed to the provision of high-quality medical care, particularly in resource-limited regions and areas with a shortage of qualified specialists (including remote provinces of Uzbekistan).

The scientific novelty of this work lies in the fact that, for the first time in uterine tumor diagnostics, a hybrid architecture was proposed that simultaneously utilizes three main imaging modalities (USG + MRI + CT). This approach makes a significant contribution to the development of multi-modal learning in medical image analysis.

Directions for future work:

- Training the model on larger-scale clinical datasets;
- Adapting the model for real-time operation (for mobile applications and clinical systems);
- Enhancing the explainability of the model (Explainable AI) using techniques such as Grad-CAM++ and Attention visualization;
- Conducting large-scale clinical trials in medical institutions and initiating the certification process.

Overall, this study represents an important step toward expanding the application of artificial intelligence in medicine, protecting women's reproductive health, and advancing digital healthcare systems. The developed hybrid algorithm can deliver real benefits not only in scientific research but also in practical clinical medicine.

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