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4th. INTERNATIONAL CONGRESS OF MODERN SCIENTIFIC RESEARCH

August 25-27, 2026

ANKARA TÜRKİYE

Editor:

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Asst. Prof. Dr. Canan TASTIMUR	An Explaınable Lıghtweıght Deep Learnıng Framework For Pharmaceutical Tablet Defect Classıfıcatıon Usıng Espnetv2	Erzincan Binali Yildirim University
Asst. Prof. Dr. Canan TASTIMUR	Brain Tumor Segmentation And Classification With A Lightweight Cnn And U-Net Based Framework	Erzincan Binali Yildirim University
Assist. Prof. Dr. Elçin MUSTAFAYEV	The Theme Of "Karabakh" In The Works Of Altay Hajiyev	Karamanoglu Mehmetbey University
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Dr. Halil İbrahim OLUCAK Dr. Mehmet KERTMEN Umut FINDIK	The Transformation Of The Textile Industry From The Perspective Of Industry 5.0: A Human-Centric, Sustainable, And Resilient Manufacturing Approach	İskur Tekstil Enerji Tic. ve San. A.Ş.
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BRAIN TUMOR SEGMENTATION AND CLASSIFICATION WITH A LIGHTWEIGHT CNN AND U-NET BASED FRAMEWORK

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ABSTRACT

In brain tumor images, the rapid and safe detection of tumor regions and determination of tumor types using computer-aided diagnostic tools is highly beneficial. Developed AI kits in this area help prevent subjective interpretation during the diagnostic process and accelerate the diagnostic process for the diagnoser. In this study, tumor segmentation and classification from brain MRI images were performed using a lightweight U-Net and a lightweight CNN architecture. Thanks to this integrated architecture, both tumor region detection and tumor type determination were addressed within the same study. The public tumor brain version used in the study includes glioma, meningioma, pituitary, and no tumor classifications. By including tumor-free regions labeled as no tumor in the version, the model's training contributes to differentiating non-tumor cases from tumor cases. In the first stage of the proposed study, accurate segmentation of tumor regions was achieved with a low number of parameters and reduced computational cost. Subsequently, classification was completed using the images. The segmentation results showed an 87.66% Dice score and an 83.40% Intersection over Union (IoU) score. The classification performance yielded a 99.92% train accuracy and a 97.83% validation accuracy. These classification results demonstrate that the proposed lightweight CNN architecture can provide high accuracy in distinguishing different tumor classes. Furthermore, the proposed approach can be used as a real-time computer-assisted diagnostic tool without requiring high computational power.

Keywords: Brain tumor, Magnetic resonance imaging, Tumor segmentation, Tumor classification, Deep learning.

INTRODUCTION

Since brain tumors vary in their relationships with surrounding tissues, growth patterns, and clinical characteristics from person to person, accurate diagnosis and treatment planning are crucial. Early diagnosis is also critical for achieving highly positive treatment outcomes. Recent advances in medical imaging technologies have increased the possibility of early detection of diseases. Magnetic resonance imaging (MRI) allows for detailed examination of brain tissue, and because the images show tumors of different sizes, densities, and anatomical locations, these images must be analyzed individually for each patient. Tumor types such as

glioma, meningioma, and pituitary tumors have different visual appearances, and the fact that these tissues share similar characteristics with surrounding healthy cells complicates tumor segmentation and classification. The irregularity of border shapes and varying sizes within tumor regions also presents a significant problem in terms of generalizability in automated image analysis systems. Traditional tumor diagnosis approaches include classical image processing techniques such as edge detection, thresholding, and manual feature extraction. However, the segmentation and classification success of these methods is highly dependent on tumor contrast, image quality, and imaging conditions. The recent popularity and widespread use of deep learning approaches have enabled automatic feature extraction and overcome the limitations of peripheral imaging. Numerous deep learning-based studies on tumor segmentation and classification exist in the literature.

Fateh et al. (2026) used 6000 public MRI brain images to solve the problem of brain tumor segmentation and classification. They performed comparative segmentation of four classes—glioma, meningioma, pituitary, and non-tumorous—using various transfer learning-based approaches. U-Net, UNet++, DeepLabV3+, SaberNet, EU-Net, etc. were used. SaberNet achieved the most successful segmentation with 80.6% weighted mIoU. In the tumor classification phase, various transfer learning architectures were utilized, such as VGG16/19, EfficientNetB0/1/2, Xception, and MobileNetV2/V3. According to the results obtained, EfficientNetB0 achieved the highest classification success with 99.20% accuracy.

Alagarsamy et al. Shiny (2024) performed segmentation and classification of brain tumor images from a dataset of public brain tumor MR images using U-Net. A CNN-based model was used to classify glioma, meningioma, and pituitary tumors. A 76% Dice score was obtained, achieving a 92% classification accuracy. Shiny (2024) processed images through pre-processing and post-processing for tumor segmentation and classification from brain MRI images. Pre-processing brought tumor regions to the forefront using the Region Growing segmentation algorithm. Tumor classification was performed using the Honey Badger Algorithm. The segmentation results were compared from pre- and post-operative images of patients, and the presence of tumor formation was examined by comparing pixel changes in the MR images. The classification accuracy reached 94.90%.

Yaseen et al. (2022) conducted a review of AI-assisted brain tumor segmentation studies. It was noted that traditional segmentation approaches and deep learning approaches were more prominent in brain tumor segmentation, and that learning-based approaches produced faster and more successful results compared to traditional approaches. Alkharaan et al. (2026) performed segmentation on 6000 MR brain images in four classes (glioma, meningioma, pituitary, and no-tumor) using U-Net++ and achieved a 90.55% Dice score. With the

EfficientNet-B1 architecture, an accuracy of 99.70% was achieved, enabling the detection of small and low-contrast brain tumors in particular.

Sulochana and Priyadharsini (2026) used Improved Anisotropic Diffusion Filtering to eliminate noise from brain tumor images in brain tumor segmentation and classification. In the next step, data augmentation was applied, and a Swin Transformer U-shaped Network was used for segmentation. In the classification of a four-class tumor dataset, they achieved a classification accuracy of 98.67% using InceptionResNetv2. Mandle et al. (2022) proposed a model for K-Means and a kernel-based support vector machine for segmentation and classification. The method steps are preprocessing, feature extraction, segmentation, and classification. A classification accuracy of 98.75% was achieved in a dataset of 160 MRI images containing benign and malignant data.

Farajzadeh et al. (2023) used deep learning models to perform classification and segmentation on MICCAI BraTS'20 benchmark brain tumor datasets. In the segmentation phase, 98.81% pixel-level accuracy was achieved, and in the classification phase, 98.93% accuracy was achieved. Ganesh et al. (2025) used deep learning-based models in brain tumor segmentation and classification. In addition to performing tumor classification with a CNN architecture from scratch, a comparison with transfer learning methods VGG16, GoogLeNet, and AlexNet showed 80% accuracy with GoogLeNet and 75% with AlexNet. They achieved a DICE score of 83.35% with binary classification and segmentation.

Saraswathi and Chakradhar (2025) presented a comparative review of methods in the literature for brain tumor segmentation and classification. Here, mostly deep learning-based approaches with high segmentation and classification success were found. Hossain et al. (2023) created a version with 300 images using images obtained from microwave brain imaging systems. As a result of preprocessing and data augmentation, they created a new deep learning architecture called MicrowaveSegNet for segmentation with 6000 images. They obtained 86.92% IoU and 93.10% Dice as a result of segmentation. With three-class classification (non-tumor, single tumor, and double tumor), they achieved 98.33% accuracy.

Aslam et al. (2025) created a new model, Multi-Modal Multi-Scale Contextual Aggregation with Attention Fusion, for segmentation of brain tumor images. In the Brats2020 version, they compared the segmentation results with architectures such as U-Net, nnU-Net, and Attention U-Net for four different classes: T1, T1Gd, T2, and T2-FLAIR. They achieved a Dice score of 85.89% in the total tumor region.

Zarenia et al. (2025) Data augmentation was first performed using the Hierarchical Multiscale Deformable Attention Module for brain tumor segmentation and classification. Fourteen tumor types that were morphologically similar to each other were classified using a public

dataset from brain tumor images. The classification accuracy was 96.5%, and the segmentation dice score reached 96.11%.

Table 1. Literature review for brain tumor segmentation and classification

Study	Method	Dataset	Metrics
Fateh et al. (2026)	Comparative segmentation using U-Net, UNet++, DeepLabV3+, SaberNet, EU-Net, and other transfer learning-based approaches. For classification, VGG16, VGG19, EfficientNetB0/B1/B2, Xception, MobileNetV2, and MobileNetV3 were evaluated.	6,000 public brain MRI images comprising four classes: glioma, meningioma, pituitary, and non-tumorous.	**Segmentation**: 80.60% weighted mIoU using SaberNet. **Classification**: 99.20% accuracy using EfficientNetB0.
Alagarsamy et al. (2024)	U-Net was employed for tumor segmentation, while a CNN-based model was used for classification. The study focused on distinguishing glioma, meningioma, and pituitary tumors.	Publicly available brain tumor MRI dataset containing glioma, meningioma, and pituitary tumor images	**Segmentation:** 76% Dice score. **Classification:** 92% accuracy.
Shiny (2024)	Image preprocessing followed by Region Growing for tumor-region segmentation. Tumor classification was performed using the Honey Badger Algorithm. Preoperative and postoperative images were compared through pixel-level analysis.	Public brain MRI tumor images, including preoperative and postoperative images.	**Classification:** 94.90% accuracy.
Alkharaan et al. (2026)	U-Net++ for segmentation and EfficientNet-B1 for tumor classification. The approach was designed to improve the detection of small and low-contrast tumor regions.	6,000 public brain MRI images divided into four classes: glioma, meningioma, pituitary, and no-tumor.	**Segmentation:** 90.55% Dice score. **Classification:** 99.70% accuracy using EfficientNet-B1.
Sulochana and Priyadharsini (2026)	Improved Anisotropic Diffusion Filtering for noise reduction, data augmentation, and Swin Transformer U-shaped Network (Swin-Unet) for segmentation. InceptionResNetV2 was employed for four-class classification.	Public four-class brain tumor MRI dataset containing glioma, meningioma, pituitary, and no-tumor classes.	**Classification:** 98.67% accuracy.
Ganesh et al. (2025)	CNN architecture developed from scratch and comparative evaluation with VGG16, GoogLeNet, and AlexNet for classification. Deep learning-based binary tumor segmentation was also performed.	Brain tumor MRI dataset; specific dataset size was NR.	**Classification:** 80% accuracy with GoogLeNet and 75% with AlexNet. **Segmentation:** 83.35% Dice score
Hossain et al. (2023)	Preprocessing and data augmentation followed by a proposed deep learning architecture named MicrowaveSegNet for segmentation and classification.	300 images, expanded to 6,000 images through preprocessing/data augmentation.	**Segmentation:** 86.92% IoU and 93.10% Dice score. **Classification:** 98.33% accuracy.

METHODOLOGY

In this section, a two-stage deep learning study is prepared for tumor detection and classification from brain tumor images. A lightweight U-Net architecture is used for segmentation, and a CNN architecture is designed from scratch for classification. The main

goal of the study is to perform automated analysis of brain MR images using architectures with a lower number of parameters and less computational load, instead of complex models with high computational costs. In the first stage, tumor regions are detected, i.e., segmented, and then the model is designed to classify these tumor types.

In the lightweight LightUNet architecture developed for tumor segmentation, low-level spatial information and high-level semantic features can be used together. The encoder section of the LightUNet architecture has four sequential feature extraction levels. In the first upsampling process, the 128-channel bottleneck feature is reduced to 64 channels, while the spatial dimension is doubled. Thanks to the skip connection structure, fine boundary and position information that might be lost during pooling operations is directly transferred to the decoder section. Figure 1 shows an overview of the LightUNet architecture.

In tumor classification, the CNN architecture built from scratch started with an initial layer of 32 channels and a 3x3 filter size, followed by 2x2 MaxPooling; then a 64-channel 3x3 filter size with a convolution layer and continued with MaxPooling again. The number of channels then increased to 128 and 256 respectively. To prevent overlearning in the proposed model, Dropout layers were added to prevent the model from memorizing incoming training data. Four different types of tumors were classified: glioma, meningioma, pituitary, and no tumor. Figure 2 presents the CNN architecture built from scratch.

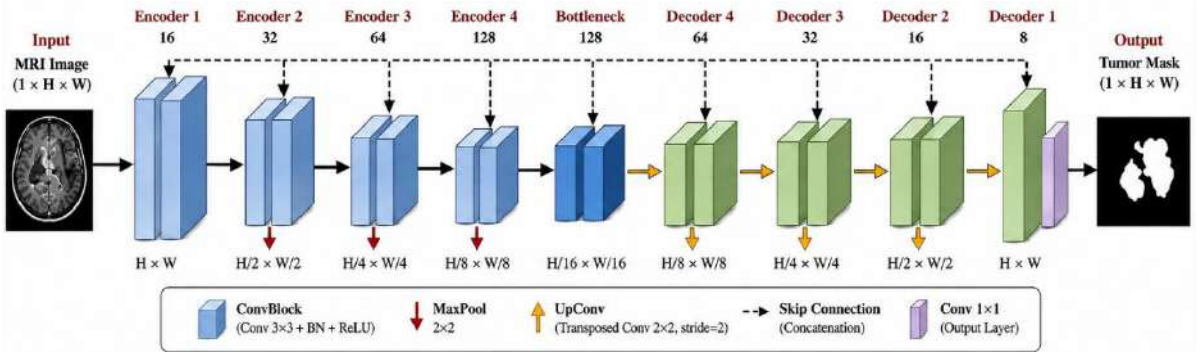


Figure 1. The overall architecture of the proposed brain tumor segmentation

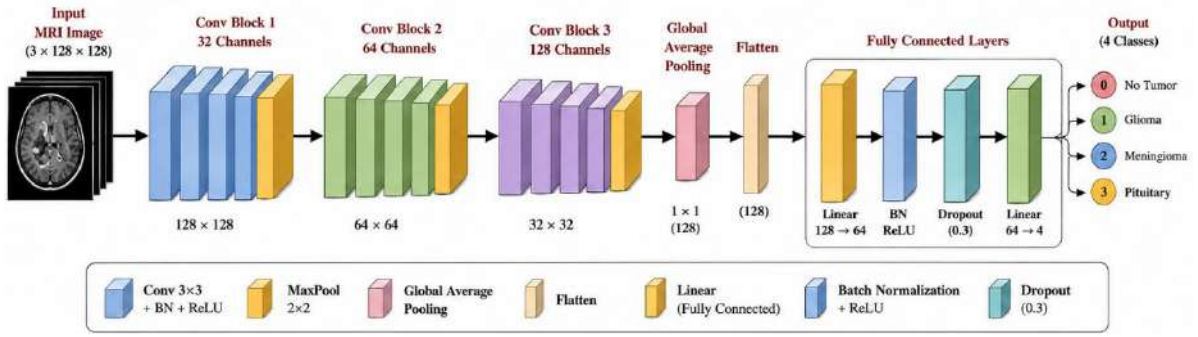


Figure 2. The overall architecture of the proposed brain tumor classification

EXPERIMENTAL RESULTS

In this study, classification metrics, complexity matrix, ROC curve, and classification score for each class were evaluated to assess the performance of the proposed model. To prove that the proposed model is quite lightweight and fast, in terms of model parameter number, model size, computational complexity, CPU inference latency, GPU inference latency, and CPU throughput. This study was conducted on a system with a 13th generation Intel Core i7-13620H central processing unit (CPU) and an NVIDIA GeForce RTX 4060 Laptop GPU graphics processing unit (GPU). Table 2 and Figure 3 shows the computational complexity of the proposed model.

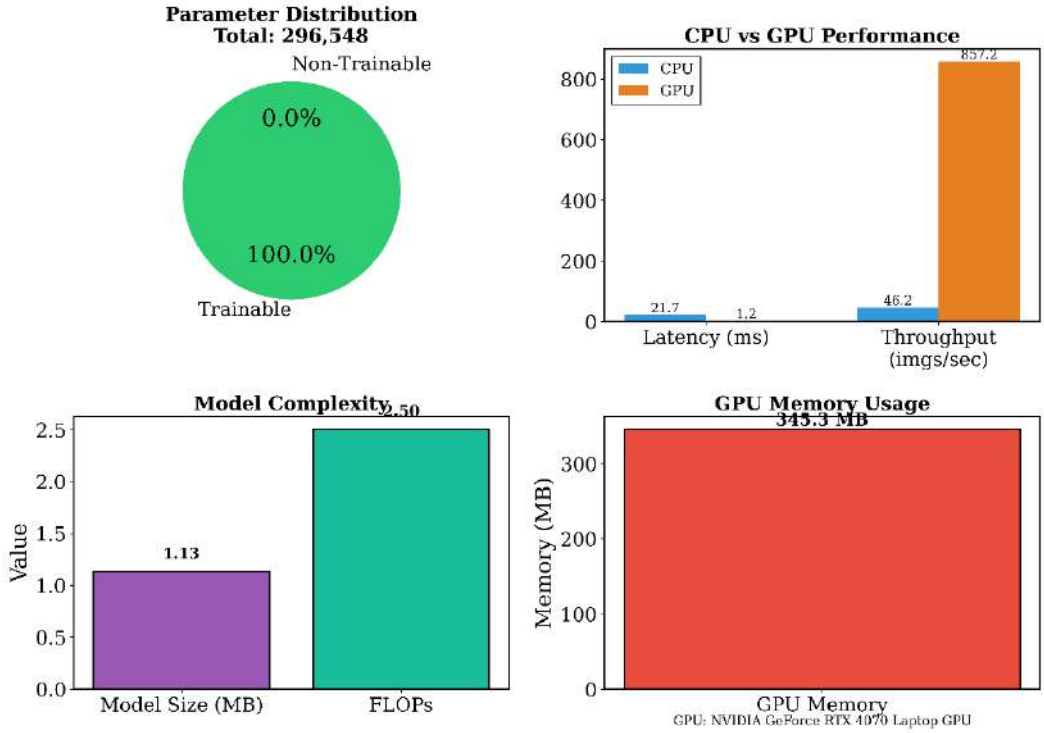


Figure 3. Comprehensive model comparsion

Table 2. Computational cost and inference performance of proposed model

Metric	Value
Params (M)	296,548
Size (MB)	1.13 MB
FLOPs (G)	2.502G
CPU Latency (ms)	21.67 ms
CPU Latency (ms)	1.17 ms
CPU Throughput	46.2 images/sec
GPU Throughput	857.2 images/sec
GPU Memory	345.3 MB

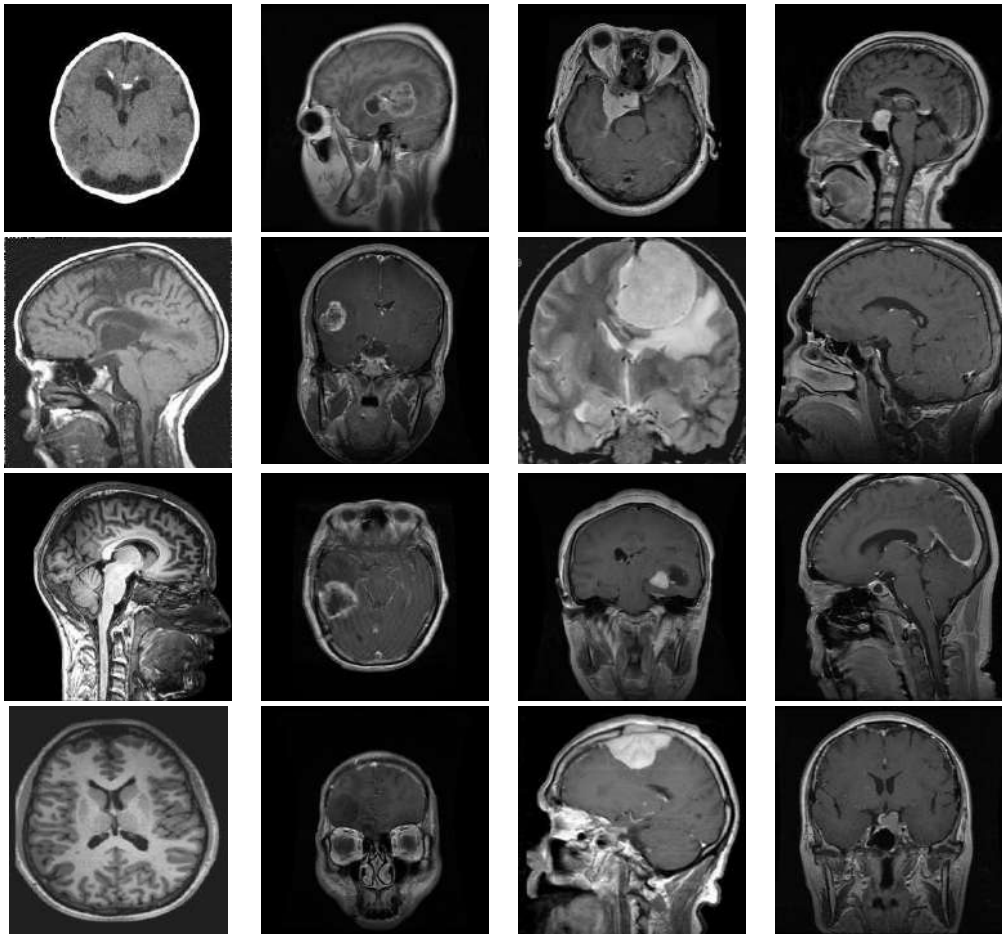
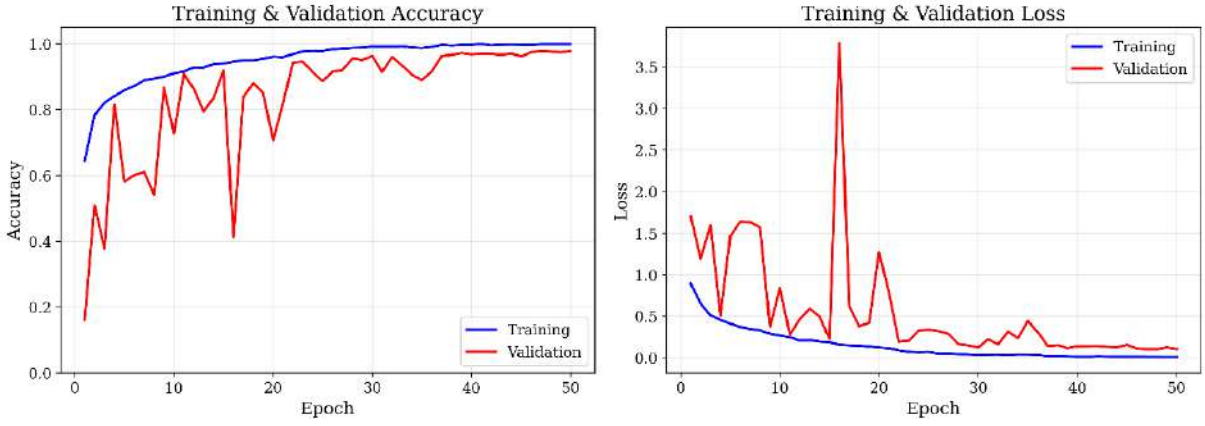


Figure 3. Sample brain tumor images belonging to the categories (a) glioma, (b) meningioma, (c) pituitary, and (d) no tumor.

Figure 3 shows an example visualization of the public brain tumor dataset used in this study. The training and validation accuracy curves and loss curves of the proposed model are shown in Figure 4. It is clear that the model successfully completed the training and did not experience overfitting. The ROC curve presented in Figure 5 supports this. In the confusion matrix in Figure 6, only 6 test samples were mislabeled, while all other classes were correctly labeled. The t-SNE visualization space presented in Figure 7 shows how well the model differentiated and grouped the sample test images.



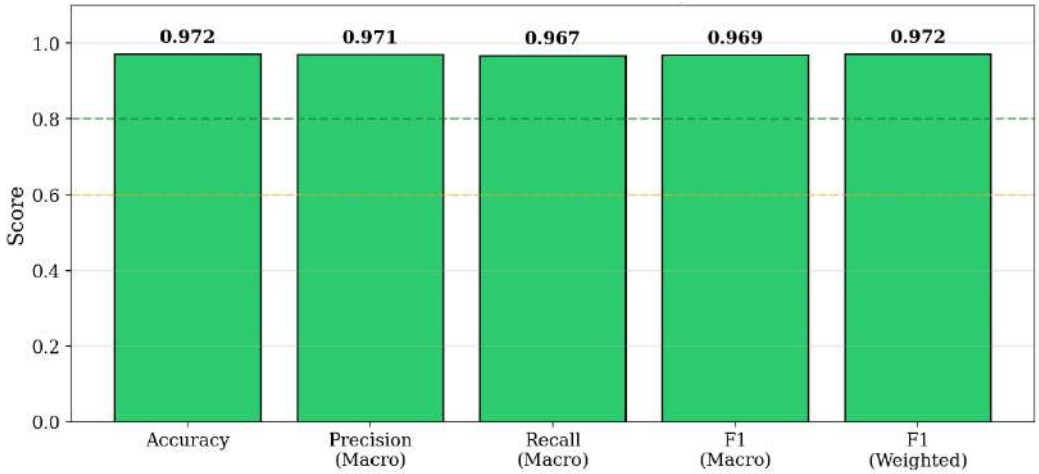


Figure 4. (a)Training and validation curves and (b) performance metrics of the proposed model

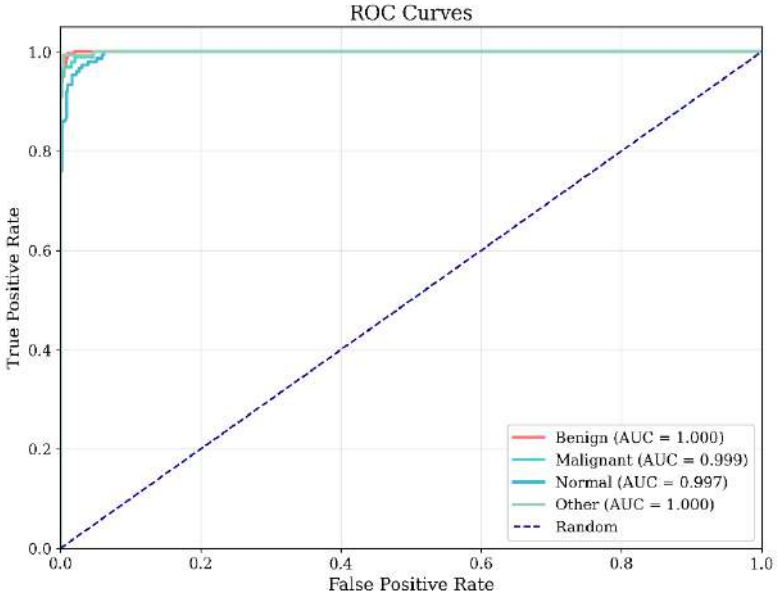


Figure 5. ROC curve of the proposed model

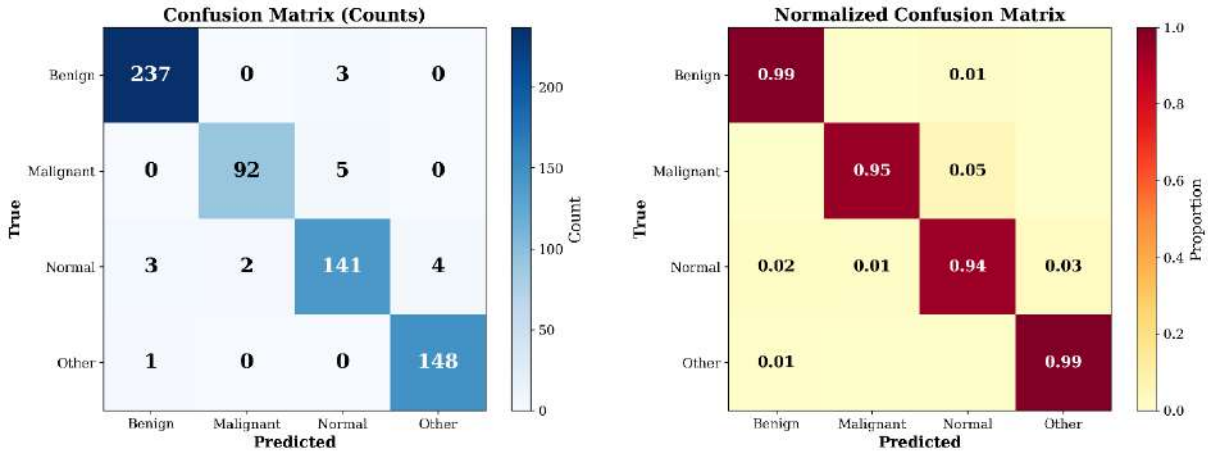


Figure 6. Confusion matrix of the proposed model

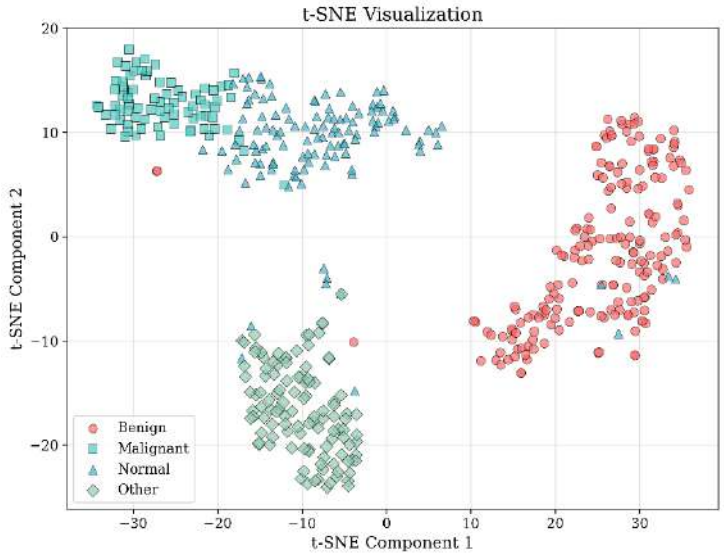


Figure 7. t-SNE visualization of the proposed model

The obtained results demonstrate that the proposed segmentation model achieves stable and consistent performance throughout the training process. The increasing Dice and IoU scores, together with the decreasing loss, indicate that the model effectively learns the tumor regions and provides reliable segmentation performance on the validation data. Figure 8 presents the training and validation curves of the segmentation model, including loss, Dice score, and IoU, while Figure 9 presents the corresponding segmentation performance results. Figure 10 presents the ROC curve of the proposed segmentation model, illustrating its ability to distinguish tumor and non-tumor pixels. Figure 11 presents the Dice and IoU scores together with the tumor pixel distribution, providing a quantitative analysis of the segmentation performance and the distribution of tumor regions. Figure 12 presents the visual comparison between the ground-truth masks and the corresponding predicted segmentation results, demonstrating the ability of the proposed model to accurately localize and delineate tumor regions.

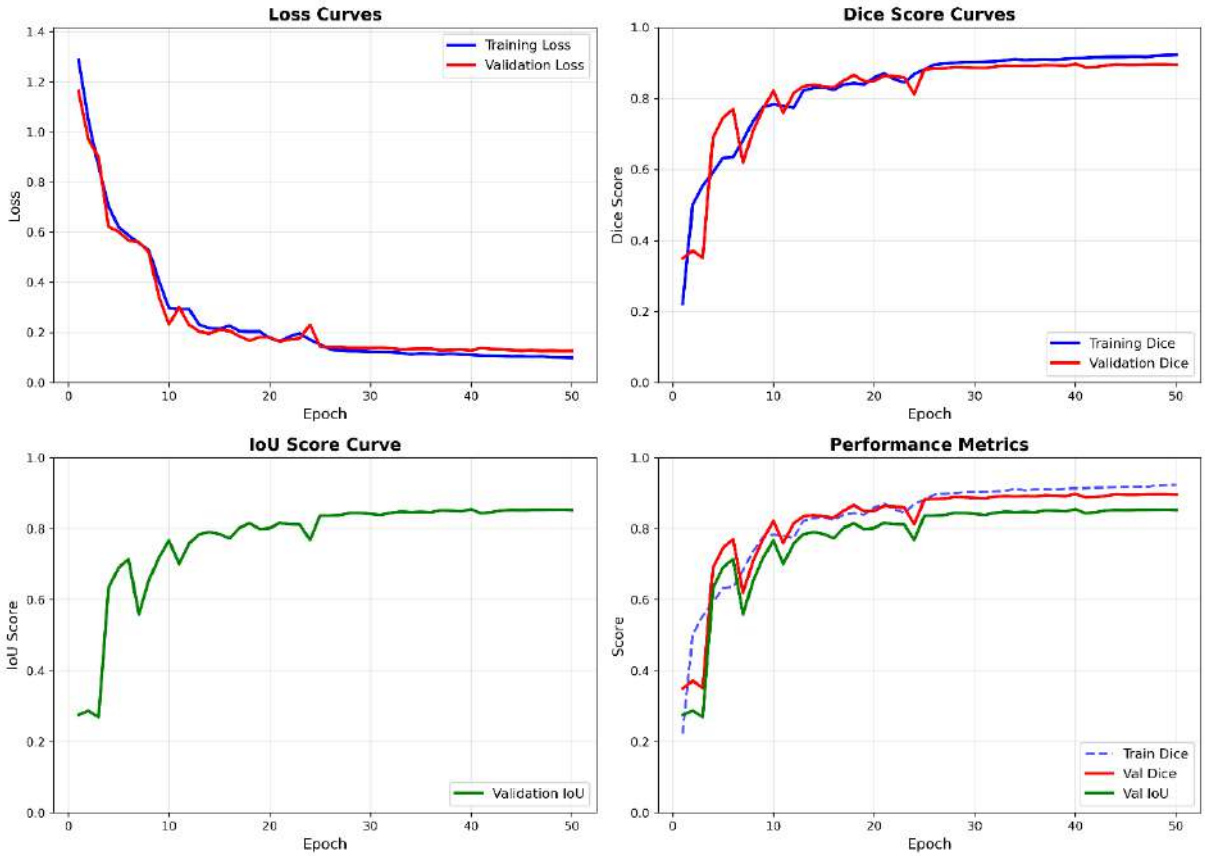


Figure 8. Training and validation curves of loss, Dice score, and IoU during the segmentation training process

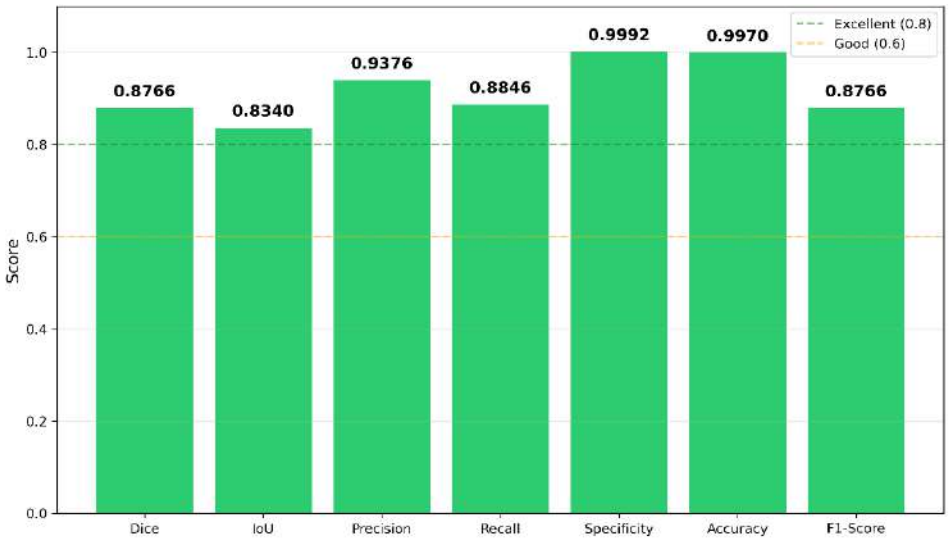


Figure 9. Segmentation Performance Evaluation of the Proposed LightUNet Model

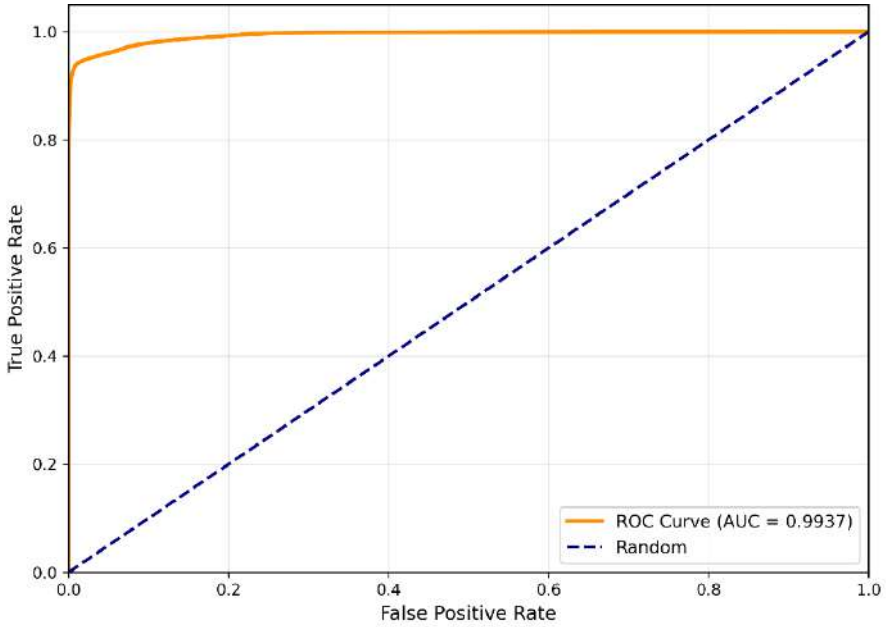


Figure 10. ROC Curve of the Proposed Segmentation Model

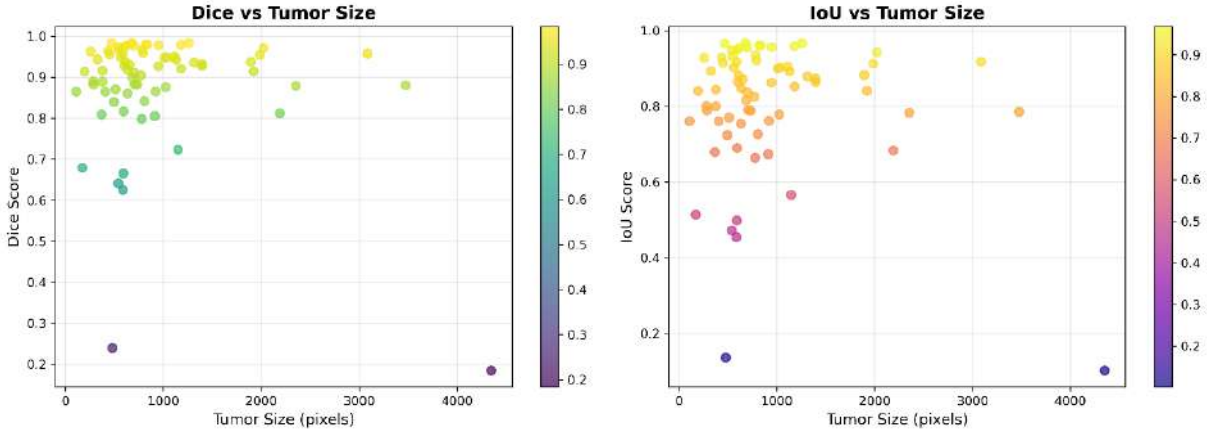
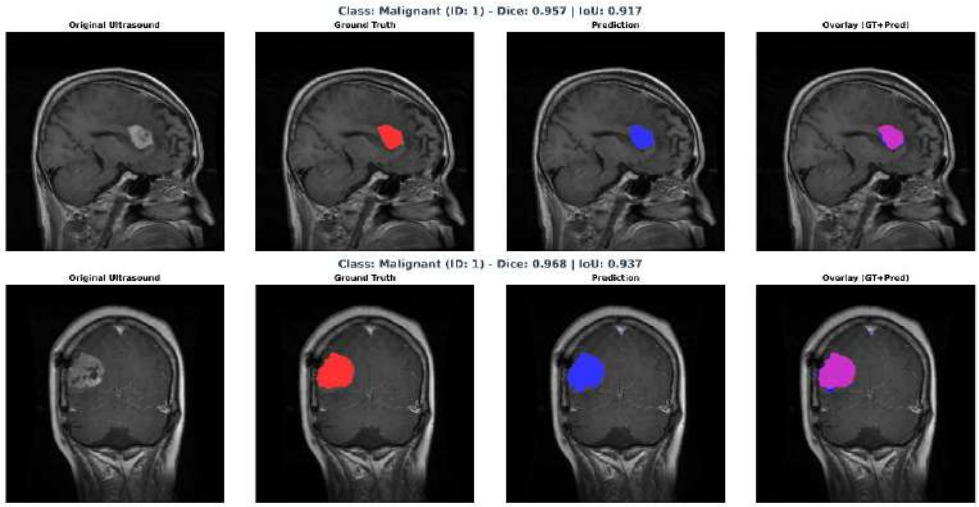


Figure 11. Dice, IoU Scores and Tumor Pixel Distribution



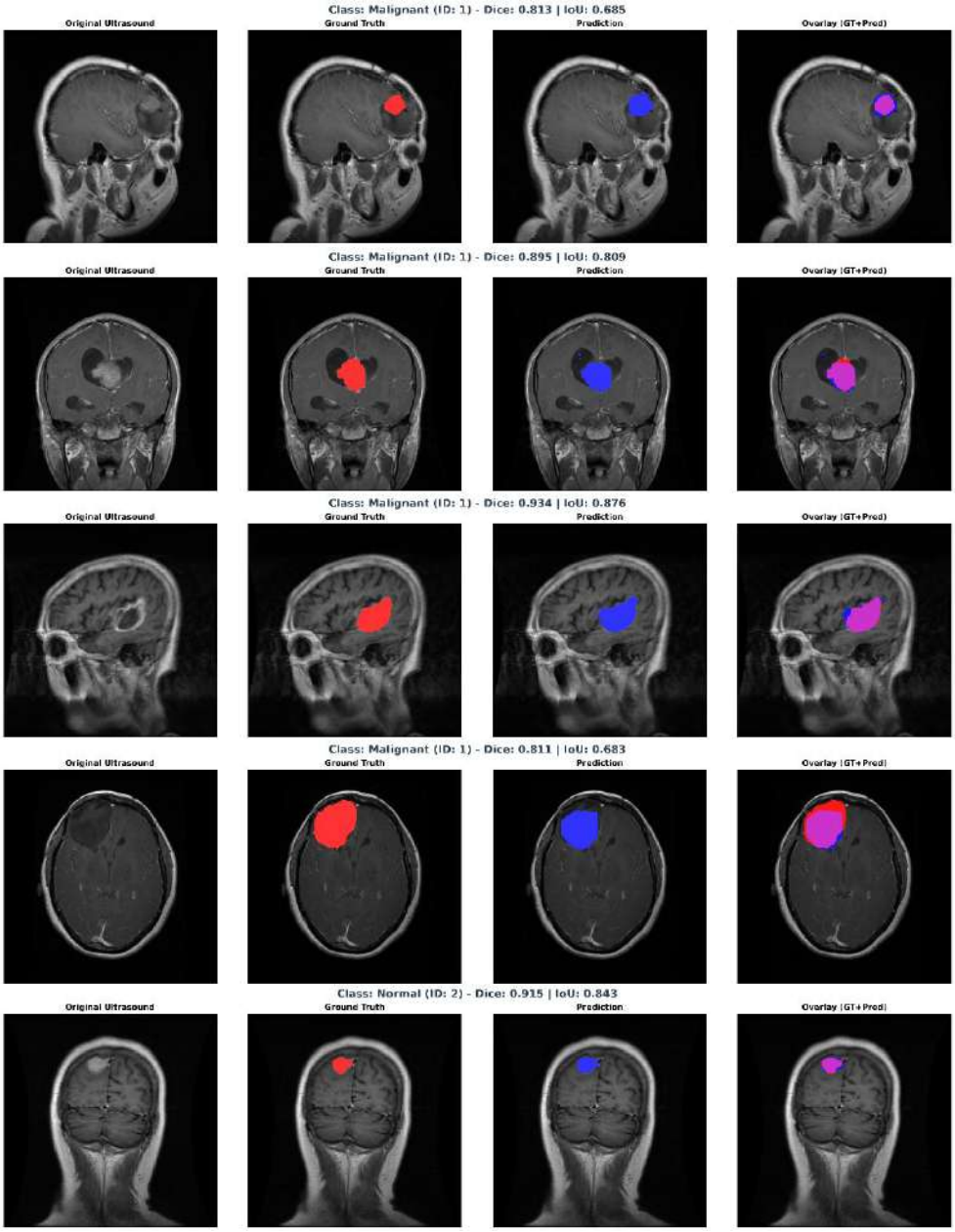


Figure 12. Ground-Truth and Predicted Tumor Segmentation Results

CONCLUSIONS

This study proposed a lightweight deep learning framework for automatic brain tumor segmentation and four-class classification using magnetic resonance (MR) images. The proposed framework consists of two complementary components: a lightweight U-Net-based architecture, LightUNet, for tumor segmentation and a compact convolutional neural network (CNN) for classification. The classification task considered four classes: glioma, meningioma, pituitary, and no tumor. The main objective was to achieve reliable image analysis while reducing unnecessary computational complexity. The proposed LightUNet achieved a Dice score of 87.66% and an Intersection over Union (IoU) of 83.40% in tumor segmentation. These results demonstrate that the model can effectively identify and delineate tumor regions from MR images. The training and validation curves, ROC analysis, Dice and IoU

evaluations, tumor pixel distributions, and visual comparisons between ground-truth and predicted masks further supported the effectiveness of the segmentation model. The use of an encoder-decoder structure with skip connections enabled the model to preserve important spatial information while extracting higher-level image features. For the classification task, the proposed lightweight CNN achieved 99.92% training accuracy and 97.83% validation accuracy across the four classes. These results indicate that the model successfully learned discriminative features for distinguishing different brain tumor types and tumor-free images. The combination of convolutional blocks, batch normalization, global average pooling, and a compact fully connected classifier provided an efficient architecture while maintaining strong classification performance. A key advantage of the proposed framework is its lightweight design. Both segmentation and classification models were developed with relatively simple architectures to reduce computational requirements while maintaining satisfactory predictive performance. This characteristic may facilitate the integration of the proposed approach into computer-aided diagnostic systems, particularly in environments where computational resources are limited.

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