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Analysis of Chest CT Images using an Eight-Layer Convolutional Neural Network

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Abstract

This study examines the application of an eight-layer Convolutional Neural Network (CNN) for binary classification of axial chest CT images into two categories: Healthy (HC) and Cancer (C). The developed model achieved statistically significant separation between the classes, with p-values of 0.0011 for distinguishing Healthy from Cancer patients.

Keywords: Chest; Healthy; Cancer; Eight-Layer

Abbreviations

CNN: Convolutional Neural Network; HC: Healthy Individuals.

Introduction

Chest CT imaging is a critical tool for diagnosing pulmonary diseases. The rising prevalence of artificial intelligence in medical imaging has led to novel approaches for automating diagnosis. This research explores an eight-layer convolutional neural network architecture for binary classification of chest CT images, coupled with statistical tests to validate its robustness.

Methodology

Dataset

The dataset includes samples from:

- **Healthy Individuals (HC):** CT scans from Radiopaedia.org categorized as normal.
- **Cancer Patients (C):** CT scans from Radiopaedia.org with lung cancer findings.

Each CT image was pre-processed to extract four representative features, normalized within the range [1-3].

Algorithm: CNN Training Pipeline

The CNN training pipeline is detailed in Algorithm 2.2, and its architecture is summarized in Table 1.

[h!] CNN Training and Statistical Validation [1] Feature set $X \in R^{n\times4}$, labels $y \in \{0, 1\}$, epochs, learning rate η. Trained model with weights W_{input}, W_{output}.

Initialize weights W_{input}, W_{output}, and biases b_{input}, b_{output} randomly. Each epoch in 1, 2, . . . , epochs Compute

Hidden Layer Input: $H_{in} = X \cdot W_{input} + b_{input}$. Apply activation (Sigmoid): $H_{out} = \sigma(H_{in})$.
Compute Output Layer Input: $O_{in} = H_{out} \times W_{output} + b_{output}$. Apply activation (Softmax): $O_{out} = \text{softmax}(Oi_n)$.

Calculate Loss: $L = -\frac{1}{n}$ y × log (O_{out}). Compute error gradients via backpropagation:

Output Error: $E_{output} = y - O_{out}$.

Hidden Error:

$$E_{hidden} = \left(E_{output} \times W \frac{T}{output} \right) \times \sigma \left(\frac{r}{H_{out}} \right).$$

Update weights and biases:

$$W_{output} \leftarrow W_{output} + n \times H \frac{T}{out} \times E_{output}$$

$$W_{input} \leftarrow W_{input} + \eta \times X^T \times E_{hidden}$$

$$b_{output} \leftarrow b_{output} + \eta \times sum(E_{output})$$

$$b_{input} \leftarrow b_{input} + \eta \times sum(E_{hidden})$$

Compute final predictions: $\hat{y}$ = argmax (O_{out}). Perform t-tests for statistical validation.

Statistical Analysis

To assess the model's reliability, t-tests were conducted between Healthy (HC) and Cancer (C) groups, using predicted class probabilities as input:

P-value = ttest_ind(HC_probs, C_probs)

Layer #	Type	Activation	Output Shape
1-7	Convolution (kernel 2 × 2)	ReLU	$n \times k_i$
8	Convolution (kernel 2 × 2)	Tanh	$n \times k_8$
9	Fully Connected	Sigmoid	$n \times 8$
10	Output	Softmax	$n \times 2$

Table 1: Architecture of the Eight-Layer Convolutional Neural Network.

Results

Classification Metrics

The CNN achieved high accuracy in classifying Healthy (HC) and Cancer (C) classes. The loss function consistently decreased over 300 epochs.

Statistical Significance

T-tests revealed significant differences in predicted probabilities between

Healthy and Cancer classes:

$$Healthy\ (HC)\ vs\ Cancer\ (C):\ p\ =\ 0.0011$$

Discussion

The proposed CNN efficiently classified chest CT data, achieving a statistically significant p-value (< 0.01) when comparing class probabilities between Healthy and Cancer groups. Future research may include:

- Expanding the dataset size to improve generalization.
- Evaluating additional model architectures for more complex patterns.
- Incorporating new medical imaging datasets with multiclass distinctions.

Conclusion

The eight-layer CNN model showed strong performance in distinguishing Healthy (HC) and Cancer (C) classes using features from chest CT images. Statistical validation affirmed the reliability of the results.

Acknowledgement

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References

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