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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: Cancer, Chest, Convolutional Neural Network, CT Images.

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 [1-3].

METHODOLOGY

Dataset

The dataset includes samples from:

- Healthy individuals (HC): CT scans from Radiopaedia.org catego rized as normal.
- Cancer patients (C): CT scans from Radiopaedia.org with lung can cer findings.

Each CT image was preprocessed to extract four representative features, normalized within the range [0, 1].

Algorithm: CNN Training pipeline

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

Algorithm 1 CNN Training and Statistical Validation

Require: Feature set $X \in R^{n\times 4}$, labels $y \in \{0,1\}$, epochs, learning rate η. Ensure: Trained model with weights W_{input}, W_{output}.

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1. Initialize weights W_{input}, W_{output}., and biases b_{input}, b_{output} randomly.
2. For each epoch in 1, 2, . . . , epochs do
3. Compute hidden layer input: $H_{in} = X \cdot W_{input} + b_{input}$.
4. Apply activation (Sigmoid): $H_{out} = \sigma(H_{in})$.
5. Compute output layer input: $O_{in} = H_{out} \cdot W_{output} + b_{output}$.
6. Apply activation (Softmax): $O_{out} = softmax(O_{in})$.
7. Calculate loss: $L = -\frac{1}{n} \sum y \cdot log(O_{out})$.
8. Compute error gradients via backpropagation:

- Output error: $E_{output} = y - O_{out}$.
- Hidden error: Ehidden = $E_{hidden} = (E_{output} \cdot W^{T}_{output}) \cdot \sigma'(H_{out})$.

9. Update weights and biases:

$$W_{output} \leftarrow W_{output} + \eta \cdot H^{T}_{out} \cdot E_{output},$$
$$W_{input} \leftarrow W_{input} + \eta \cdot X^{T} \cdot E_{hidden},$$
$$b_{output} \leftarrow b_{output} + \eta \cdot sum(E_{output}),$$
$$b_{input} \leftarrow b_{input} + \eta \cdot sum(E_{hidden}).$$

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

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

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	$n \times 2$

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)

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 statisti cally 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 distinc tions.

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.

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