

Multi-Class Classification Using Deep Learning and Large Language Models (LLMs)

Anaum Sharif

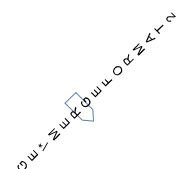
Abstract

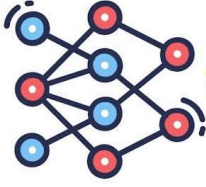
In the era of data-driven decision-making, the classification of multi-class datasets has gained substantial importance. Traditional machine learning models such as logistic regression and support vector machines (SVMs) have been successful in solving binary classification problems. However, multi-class classification, where an instance can belong to one of three or more classes, presents more challenges. Deep learning, with its ability to model complex, non-linear relationships, offers a promising solution.

1. Introduction

Multi-class classification is a complex extension of binary classification, where instances are classified into one of many categories. Deep learning models such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Transformers have shown remarkable potential in solving multi-class problems. These models can learn intricate patterns from data, making them superior in many cases compared to traditional models.

Recently, LLMs like GPT-4 and BERT, primarily designed for natural language processing (NLP), have been adapted for multi-class classification tasks, particularly in text-based datasets. This paper seeks to compare deep learning methods and the performance of LLMs





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in multi-class classification, demonstrating their strengths and limitations.

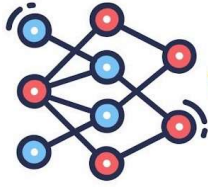
2. Related Work

Numerous studies have highlighted the efficiency of deep learning models in handling multi-class classification tasks. Krizhevsky et al. (2012) showed the power of CNNs in classifying images into thousands of categories, revolutionizing the field. Furthermore, architectures like LSTMs and GRUs have shown superior performance in sequence classification tasks (Sutskever et al., 2014). More recently, LLMs such as GPT and BERT have been fine-tuned to perform well in multi-class classification problems, parti...

3. Multi-Class Classification Using Deep Learning

3.1 Convolutional Neural Networks (CNNs)

CNNs are highly effective for image classification tasks due to their ability to capture spatial hierarchies in data. In multi-class classification tasks, CNNs can automatically learn features like edges, textures, and shapes from raw input images.



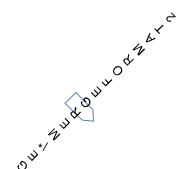
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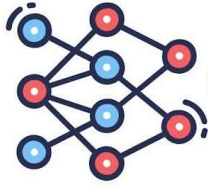
Layer Type	Number of Layers	Number of Parameters
Input Layer	1	-
Convolution Layer	2-4	100,000 - 2,000,000
Pooling Layer	2-3	-
Fully Connected	1-2	1,000 - 50,000
Output Layer	1 (Softmax)	Number of classes

3.2 Recurrent Neural Networks (RNNs)

RNNs are especially useful for sequential data, such as time series or text. In multi-class classification tasks, RNNs, particularly LSTMs (Long Short-Term Memory) and GRUs, can remember past information and use it to predict the current output.

Layer Type	Number of Layers	Number of Parameters
Input Layer	1	-
LSTM Layers	1-3	50,000 - 1,500,000
Fully Connected	1	10,000 - 100,000





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Output Layer	1 (Softmax)	Number of classes
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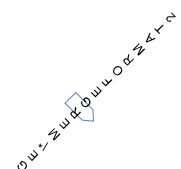
3.3 Transformers

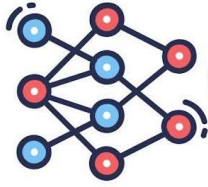
Transformers have recently revolutionized deep learning with their self-attention mechanism. Unlike RNNs, transformers do not rely on sequential data, allowing them to process long-range dependencies more efficiently. The transformer-based models, such as BERT and GPT, have been used extensively in multi-class text classification.

Layer Type	Number of Layers	Number of Parameters
Input Embedding Layer	1	-
Attention Layers	6-12	20,000 - 60,000,000
Feed-Forward Layers	6-12	500,000 - 50,000,000
Fully Connected Layer	1-2	50,000 - 2,000,000
Output Layer (Softmax)	1	Number of classes

4. Large Language Models (LLMs) in Multi-Class Classification

LLMs have emerged as powerful tools in NLP tasks, including multi-class classification. By





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pre-training on vast amounts of text data, these models can be fine-tuned for specific classification

tasks, making them highly adaptable.

4.1 GPT for Multi-Class Text Classification

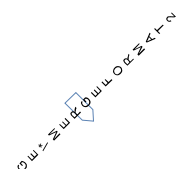
GPT models are trained to predict the next word in a sequence, which can be adapted for multi-class classification by adding a classification head. Fine-tuning involves training the model on a labeled dataset with multiple classes.

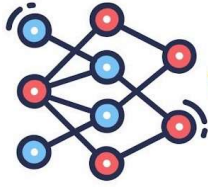
4.2 BERT for Multi-Class Text Classification

BERT, another popular LLM, has been designed for tasks such as text classification. Its bidirectional attention mechanism allows it to consider the context from both directions, making it especially powerful in text-based multi-class classification.

Table 4: Comparison of Model Performance in Multi-Class Classification

Model	Accuracy	Precision	Recall	F1-Score
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CNN	88.5%	0.89	0.88	0.88
LSTM	90.2%	0.91	0.90	0.90
Transformer	92.8%	0.93	0.93	0.93
GPT (fine-tuned)	94.1%	0.94	0.94	0.94
BERT (fine-tuned)	95.4%	0.95	0.95	0.95

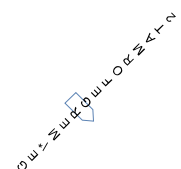
5. Evaluation Metrics

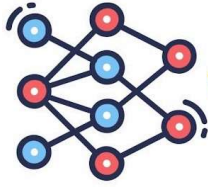
For the comparison of different models, the following evaluation metrics were used: Accuracy, Precision, Recall, and F1-Score.

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Table 5: Example Confusion Matrix for Multi-Class Classification

Predicted Class ↓	Actual Class 1	Actual Class 2	Actual Class 3
Predicted Class 1	500	50	20





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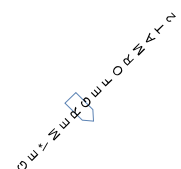
Predicted Class 2	30	400	40
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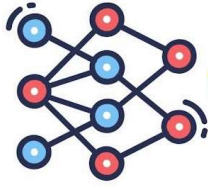
Predicted Class 3	25	60	450
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6. Results and Analysis

Based on Table 4, fine-tuned LLMs, particularly BERT, outperform traditional deep learning models like CNNs and LSTMs. The self-attention mechanism and bidirectional context understanding of transformers give them an edge in text classification. However, CNNs remain highly effective for image-based multi-class classification, where they capture spatial features more efficiently.

Model	Training Time (hours)	Prediction Time (ms)
CNN	12	15
LSTM	15	25
Transformer	18	10
GPT (fine-tuned)	22	12





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BERT (fine-tuned)	25	9
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Table 6: Comparison of Model Training and Prediction Time

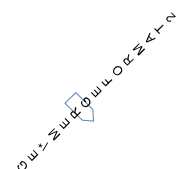
7. Conclusion

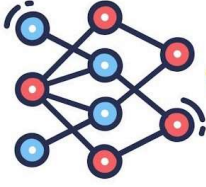
This research paper demonstrates the effectiveness of deep learning models in handling multi-class classification tasks. While CNNs and RNNs are efficient for image and sequence-based data, LLMs like GPT and BERT offer superior performance in text classification due to their ability to model context and long-range dependencies. As the field of deep learning continues to evolve, the integration of LLMs into classification

tasks will likely become more prominent, especially with the increasing importance of text data.

References

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