MULTI-LABEL IMAGE CLASSIFICATION FOR ONLINE EDUCATIONAL PLATFORMS USING SGD

[1]POLISETTI SATYA LAKSHMI, [2]Y SRINIVAS RAJU
[1]Students, Department of MCA, B V Raju College, Bhimavaram Ap
[2]Assistant Professor, Department of MCA, B V Raju College, Bhimavaram Ap

ABSTRACT

With the rapid growth of online educational platforms, organizing and categorizing learning content such as images, diagrams, text, and headers has become essential for improving content accessibility and user experience. Manual classification of educational images is time-consuming and inefficient, especially with large datasets. This project proposes a multi-label image classification system using Convolutional Neural Networks (CNN) optimized with Stochastic Gradient Descent (SGD) for accurately classifying learning images into multiple categories. The proposed system utilizes a deep learning-based CNN architecture combined with SGD optimizer, configured with a learning rate of 0.1 and momentum of 0.9, along with binary cross-entropy as the loss function. These optimizations enhance the model's learning capability and improve classification performance. The dataset is preprocessed through normalization and splitting into training and testing sets in an 80:20 ratio. The trained model is then used to classify images into categories such as diagrams, text, headers, and mathematical content. Experimental results demonstrate that the proposed CNN-SGD model achieves an accuracy of over 96%, with strong performance across evaluation metrics including precision, recall, and F1-score. Visualization tools such as confusion matrices and training accuracy graphs further validate the model's effectiveness. This system provides an efficient and scalable solution for automatic content classification in e-learning platforms, enhancing content organization and user experience.

Keywords : Multi-Label Classification, CNN, SGD Optimizer, Image Classification, E-Learning, Deep Learning, Binary Cross-Entropy, Educational Data, Computer Vision, Content Categorization

I. INTRODUCTION

The rapid expansion of online educational platforms has led to an enormous increase in digital learning resources, including images such as diagrams, mathematical expressions, text snippets, and headers. Efficient organization and classification of these images are essential for improving content accessibility, searchability, and overall user experience. Traditional methods of content classification rely on manual tagging and rule-based systems, which are time-consuming, error-prone, and not scalable for large datasets. As a result, there is a growing need for automated systems that can accurately classify educational images with minimal human intervention.

With the advancement of deep learning and computer vision, Convolutional Neural Networks (CNNs) have become the most effective approach for image classification tasks. CNNs can automatically learn hierarchical features from images, such as edges, textures, and complex patterns, enabling them to classify images with high accuracy. In multi-label classification, an image can belong to multiple categories simultaneously, making it more challenging than traditional single-label classification. To address this, appropriate loss functions such as binary cross-entropy are used to handle multiple labels effectively. Additionally, optimization techniques like Stochastic Gradient Descent (SGD) play a crucial role in improving model performance by efficiently updating model weights during training.

In this project, a CNN-based multi-label image classification system is proposed for categorizing educational images. The system uses SGD optimizer with optimized parameters to enhance training efficiency and accuracy. The dataset is preprocessed and divided into training and testing sets, and the model is evaluated using standard metrics such as accuracy, precision, recall, and F1-score. The system also includes modules for user interaction, model training, and real-time image classification. This approach provides an efficient and scalable solution for content classification in modern e-learning platforms.

II SURVEY OF RESEARCH

1. Traditional Image Classification Techniques

Early image classification methods relied on manual feature extraction techniques such as Scale-Invariant Feature Transform (SIFT), Histogram of Oriented Gradients (HOG), and Local Binary Patterns (LBP). These features were then used with classifiers like Support Vector Machines (SVM) or k-Nearest Neighbors (k-NN). While these approaches achieved moderate success, they required extensive domain knowledge and were not effective for complex or large-scale datasets. Research indicates that traditional methods struggle with variations in image quality, orientation, and content complexity. These limitations led to the adoption of deep learning techniques that can automatically extract features from raw image data.

2. Deep Learning for Image Classification

Deep learning, particularly Convolutional Neural Networks (CNNs), has revolutionized image classification tasks. CNNs are capable of learning hierarchical features directly from images, eliminating the need for manual feature engineering. Studies show that CNN-based models outperform traditional methods in terms of accuracy and scalability. Architectures such as AlexNet, VGGNet, and ResNet have demonstrated high performance in large-scale image classification tasks. This project utilizes CNN to classify educational images efficiently and accurately.

3. Multi-Label Image Classification

Unlike single-label classification, multi-label classification allows an image to belong to multiple categories simultaneously. Research highlights that this approach is more suitable for real-world applications where images may contain multiple features or concepts. Techniques such as sigmoid activation and binary cross-entropy loss are commonly used to handle multi-label classification problems. However, challenges such as label imbalance and increased complexity need to be addressed. This project implements multi-label classification to accurately categorize learning images into multiple classes.

4. Optimization Techniques in Deep Learning

Optimization algorithms play a crucial role in training deep learning models. Stochastic Gradient Descent (SGD) is one of the most widely used optimization techniques due to its simplicity and effectiveness. Research shows that using appropriate learning rates and momentum values can significantly improve model convergence and performance. Variants such as Adam and RMSProp are also popular, but SGD with momentum often provides better generalization. This project employs SGD with optimized parameters to enhance CNN performance.

5. Applications in E-Learning Systems

Image classification has numerous applications in e-learning platforms, including content organization, automated tagging, and personalized learning recommendations. Research indicates that automated classification systems improve user experience by enabling efficient content retrieval and management. These systems are particularly useful in large-scale educational platforms where manual organization is impractical. This project contributes to this domain by providing an automated solution for classifying learning images.

6. Evaluation Metrics and Visualization Techniques

Evaluating the performance of image classification models is essential to ensure reliability. Common metrics include accuracy, precision, recall, and F1-score. Confusion matrices are used to analyze classification performance and identify misclassifications. Visualization techniques such as training accuracy graphs and loss curves help in understanding model behavior during training. Research emphasizes the importance of using multiple metrics for comprehensive evaluation. This project uses standard evaluation metrics and visualization tools to validate model performance.

III. WORKING METHODOLOGY

The proposed system begins with data collection and preprocessing of educational images, which include categories such as diagrams, text, headers, and mathematical content. The dataset is loaded into the system and undergoes preprocessing steps such as image resizing, normalization, and labeling. These steps ensure that all images are in a consistent format suitable for model training. Data is then split into training and testing sets in an 80:20 ratio. This separation allows the model to learn from one portion of the data and be evaluated on unseen data, ensuring reliable performance assessment. Proper preprocessing improves model accuracy and helps in efficient learning.

In the next phase, a Convolutional Neural Network (CNN) model is implemented for multi-label image classification. The model consists of multiple layers including convolutional layers for feature extraction, activation functions such as ReLU, pooling layers for dimensionality reduction, and fully connected layers for classification. The model is trained using the Stochastic Gradient Descent (SGD) optimizer with a learning rate of 0.1 and momentum of 0.9, along with binary cross-entropy loss to handle multi-label outputs. During training, the model learns patterns and relationships between image features and labels. Hyperparameters such as batch size and number of epochs are tuned to achieve optimal performance.

Finally, the trained model is used for classification and evaluation. Users can upload new images through the system interface, and the model predicts the corresponding categories. The system provides outputs in both textual and graphical formats, including confusion matrices and accuracy graphs. Performance is evaluated using metrics such as accuracy, precision, recall, and F1-score. Visualization tools help in analyzing model behavior and performance trends. This methodology ensures an efficient, accurate, and scalable solution for multi-label image classification in online educational platforms.

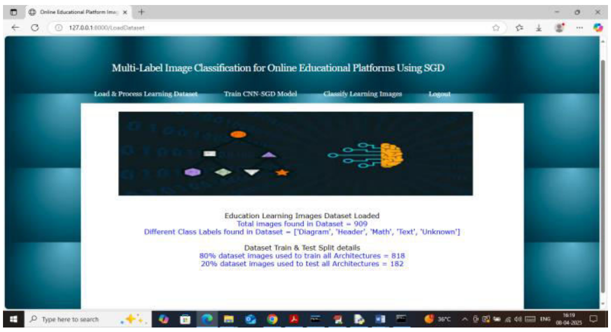
IV RESULTS EXPLANATIONS

In propose project we are utilizing CNN algorithm to classify various learning images such as Maths, Text, Header etc. To fine tune CNN performance we have utilize SGD (stochastic gradient descent) optimizer with 0.1 as the optimal learning rate and 0.9 as momentum and then utilize loss function as binary cross-entropy.

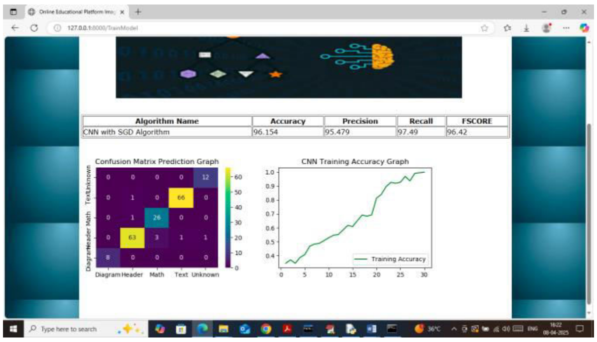
After optimizing CNN with SGD and binary loss we are able to get more than 96% accuracy on learning images classification.

To implement this project we have designed following modules

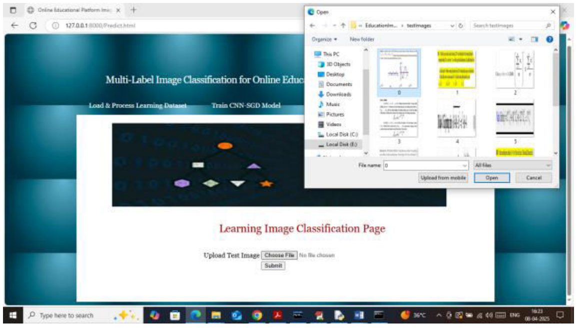
1) New User Register: user can sign up with the application
2) User Login: user can login to system
3) Load & Process Learning Dataset: using this model will load and normalize all dataset images and then split into train and test where application using 80% images for training and 20% for testing
4) Train CNN-SGD Model: 80% training images will be input to deep learning CNN algorithm to trained a model and this model will be applied on 20% test images to calculate prediction accuracy
5) Classify Learning Images: using this module user can upload test image and then CNN model will classify type of learning image
6) Model visualization: model training accuracy graph and test data confusion matrix classification graph will be visualized using this module.



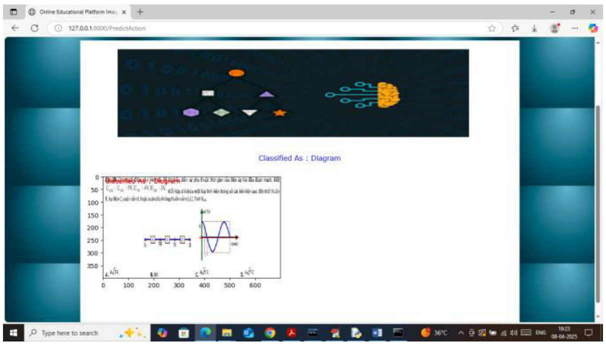
In above screen can see number of images loaded and processed from dataset and then can see train and test size. Now click on 'Train CNN-SGD Model' link to train al CNN algorithm and then will get below page



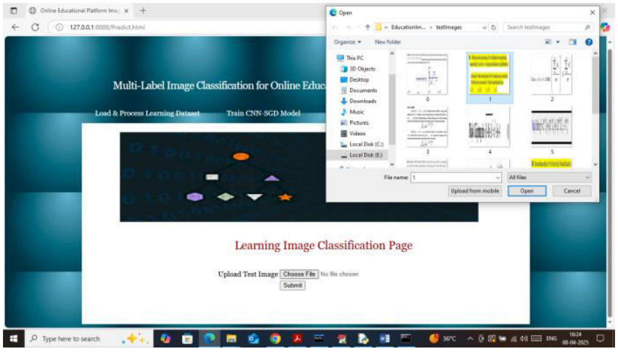
In above screen in table format can see accuracy, precision, recall, FSCORE of CNN algorithm. In above screen can see CNN can classify Learning Images with an accuracy of 96%. In confusion matrix graph x-axis represents Predicted Labels and y-axis represents true labels and then yellow and green boxes in diagonal represents correct prediction count and remaining blue boxes represents incorrect prediction count which are very few. In second graph can see training accuracy of CNN where x-axis represents 'Number of training epochs' and y-axis represents 'accuracy' and can see with each increasing epoch accuracy got increased and reached closer to 1. Now click on 'Classify Learning Images' link to get below page



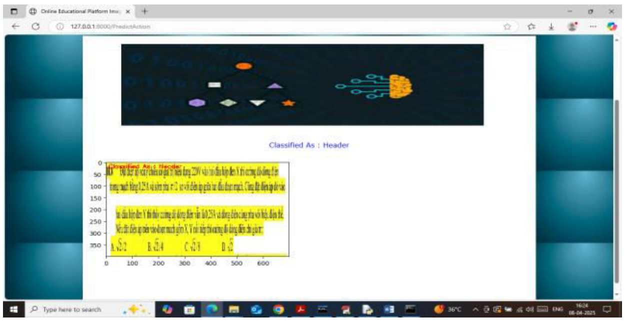
In above screen selecting and uploading image and then click on buttons to get below page



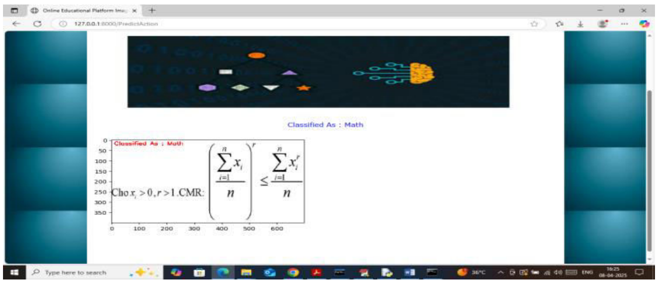
In above screen in blue and red text can see uploaded image classified as 'Diagram' and similarly you can upload and test other images



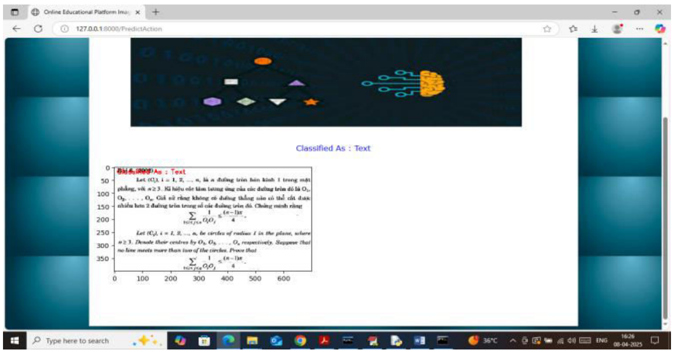
In above screen uploading another image and below is the output



Above image is classified as Header



Above image is classified as 'Math'.



Above image classified as 'Text'.

V. CONCLUSION

The proposed multi-label image classification system using CNN with SGD optimization provides an efficient and accurate solution for categorizing educational images in online learning platforms. By leveraging deep learning techniques, the system is capable of automatically extracting complex features from images and assigning multiple relevant labels such as diagrams, text, headers, and mathematical content. The use of Stochastic Gradient Descent (SGD) with optimized parameters, along with binary cross-entropy loss, significantly enhances the model's performance and generalization ability. Experimental results demonstrate that the system achieves high accuracy of over 96%, with strong performance across precision, recall, and F1-score metrics. Visualization tools such as accuracy graphs and confusion matrices further validate the effectiveness of the model. The system also provides a user-friendly interface for image classification and model interaction. Overall, this project offers a scalable and reliable solution for automated content classification, improving content organization, searchability, and user experience in modern e-learning platforms.

REFERENCES

[1] Y. LeCun, Y. Bengio, and G. Hinton, "Deep learning," *Nature*, vol. 521, pp. 436–444, 2015.

[2] A. Krizhevsky, I. Sutskever, and G. Hinton, "ImageNet classification with deep convolutional neural networks," in *Proc. NIPS*, 2012.

[3] K. Simonyan and A. Zisserman, "Very deep convolutional networks for large-scale image recognition," 2014.

[4] K. He, X. Zhang, S. Ren, and J. Sun, "Deep residual learning for image recognition," in *Proc. CVPR*, 2016.

[5] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*, MIT Press, 2016.

[6] D. P. Kingma and J. Ba, "Adam: A method for stochastic optimization," 2014.

[7] L. Bottou, "Stochastic gradient descent tricks," *Neural Networks: Tricks of the Trade*, Springer, 2012.

[8] F. Chollet, "Keras," 2015.

[9] M. Abadi *et al.*, "TensorFlow: Large-scale machine learning on heterogeneous systems," 2016.

[10] J. Deng *et al.*, "ImageNet: A large-scale hierarchical image database," in *Proc. CVPR*, 2009.