Explainable Text Recognition and Classification using Neural Network and Fuzzy Logic

Shalini Puri[1], Midhunchakkaravarthy Janarthanan[2], Ganesh Khekare[3]
[1]Lincoln University College Malaysia; [2]Lincoln University College Malaysia; [3]Vellore Institute of Technology, Vellore, India
eng.shalinipuri30@gmail.com
midhun@lincoln.edu.my
khekare.123@gmail.com

Abstract: Nowadays, fuzzy logic and deep learning are useful methods for deriving incredibly precise predictions from complicated data sources. Neural networks have shown promise in generating captions and language translation. Convolutional neural networks are still the most popular approach for image classification problems, nevertheless. Furthermore, training models with several layers of interconnected artificial neurons is a component of deep learning, commonly referred to as deep neural networks. A neural network and fuzzy logic-based explainable text identification and detection model is proposed in this paper. It provides a detailed explanation of its steps.

Keywords: Multilingualism; Neural Network; XAI; Text Classification; Fuzzy Logic; Sustainable Learning.

Introduction

Fuzzy logic and deep learning are two effective methods in artificial intelligence [10]. Fuzzy logic integrates Deep Learning (DL) to assist DL in selecting the needed features and operating autonomously, enabling the development of dependable systems with rich DL knowledge even in the absence of manually labeled data [3]-[7]. The system's classification label selection will then be explained using fuzzy logic that analyzes these characteristics [10]. Deep Neuro-Fuzzy Models (DNFM) have been successfully applied in real-world applications, such as multilingual document classification [5] by combining the efficient learning process of Deep Neural Networks (DNNs) with the reasoning capacity of fuzzy inference systems. As the applications of learning models have expanded in multilingualism, there has been great interest in their explainability. Instead of emphasizing the connections between agent states and actions, the majority of explainable models now in use concentrate on enhancing the explainability of an agent's observations.

However, the massive volumes of multilingual, domain-diverse textual data generated by the exponential growth of social media and internet-based content are making successful explainable classification more challenging. While Deep Learning (DL) and Conventional Artificial Neural Network (ANN) models often achieve high performance, they work as "black boxes," offering no insight into their decision-making

processes. Conversely, Fuzzy Set Theory, which was created to address ambiguity and uncertainty, has shown itself to be useful in handling imprecise and incomplete data across diverse domains. Similarity metrics and rule extraction techniques play a significant role in fuzzy-based text classification, while enhancing interpretability. Nevertheless, current hybrid models rapidly experience sluggish convergence, sensitivity to noise, and diminished efficacy on incomplete multilingual datasets [8].

The proposed explainable text recognition and classification model recognizes and classifies multilingual text using the learning capabilities of NN, while ensuring interpretability through fuzzy logic. It applies NN to learn complex patterns and performs text classification, and fuzzy logic to convert learned features into human-understandable rules. It achieves the explainability through fuzzy rules and linguistic reasoning. This paper is structured as follows: The following section presents the background of related text recognition and classification models. Following that, it discusses the proposed methodology for text recognition and classification using XAI, NN, and fuzzy logic. Finally, the paper concludes with a discussion on future recommendations.

Background

The research work proposed a Hindi printed text document classification model using SVM and fuzzy matching [1], and an English printed and handwritten text document classification system [2]. Another work [3] applied XAI-based fuzzy integrated NN using Choquet integral (ChI), improved ChIMP, and synthetic validation. Next work [4] inferred multilingual domain-specific word embeddings from a large multilingual Wikipedia dataset. The study [5] reviewed various DNFM architectures and their optimization methods. It found that the DNFS architectures performed 11.6% better than non-fuzzy models, with an overall accuracy of 81.4%. DNFM with metaheuristic optimization methods achieved an accuracy of 93.56%, which was 21.1% higher than DNFS models using gradient-based methods. Some studies have discussed the DNFM optimization using classical gradient-based approaches, which affected network performance when solving highly nonlinear problems.

Another work [6] applied XAI-based reinforcement learning agents by reconstructing fuzzy if-then rules. The study [7] expanded the explainable e-Discovery and interpretable fuzzy ARTMAP NN to include a fuzzy subset for ranking documents and was evaluated with several corpora. It demonstrated the textual and graphical interpretability for TF-IDF, GloVe, and Word2Vec. Another study [8] classified the data using an optimized fuzzy + Alex Net NN and improved cuckoo search optimization. It handled the missing values using k-means clustering. Another study [9] discussed the applications of fuzzy NN in social media customer behavior analysis and designed the online marketing techniques. It classified and quantified features, including content topic features, behavioral frequency features, social interaction features, and time series features. The review [10] discussed the applications of deep learning and fuzzy logic.

The work [11] proposed a fuzzy-centered explainable framework for reinforcement learning to interpret the relationships between agent states and actions. The implementation was applied to four Atari games to enhance the agent's explainability both globally and locally. Another review [12] addressed the primary concerns for the XAI-based multilingual document classification and provided analytical findings derived

from previous studies. Another work [13] extracted and recognized the text in the scene image using a self-attention Convolutional Neural Networks (CNNs) + fuzzy DNN. It first eliminated noise and enhanced image quality, fed the extracted features into a self-attention-based CNN to separate text and non-text components, and lastly recognized the characters. Another work [14] classified real-time on-device documents using Optical Character Recognition (OCR), CNN, and FuzzyWuzzy logic. It trained Efficient Net and Mobile Net models, combined visual and textual features, and achieved 97.1% accuracy on datasets, with real-time processing in 2.3 seconds. Another model [15] classified the educational information objects, such as manuals, lectures, syllabuses, and textbooks, using NN and fuzzy logic.

The Proposed Methodology

The proposed explainable text recognition and classification model begins with inputting the text documents. It then preprocesses the text by tokenizing it, removing stop words, and stemming. Next, it extracts features by calculating term frequencies and inverse document frequencies, as well as determining word embeddings. Then it classifies them using an NN by applying hidden layers and feature learning. Its fuzzy logic module performs fuzzification, builds the fuzzy rules, and works with an inference engine. It extracts Fuzzy if-then rules at any stage of training thanks to this explainable neural network design, which is also geometrically interpretable. Lastly, it interprets the model's output using class labels, confidence, and fuzzy rule explanation.

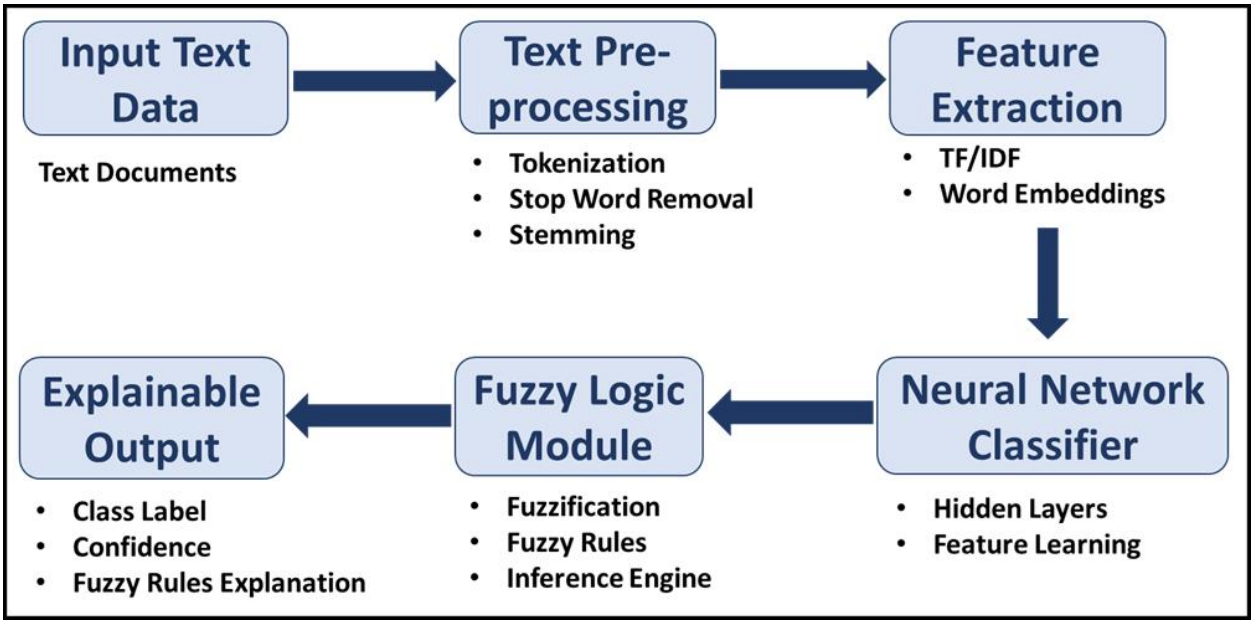

Figure 1. Architecture of the proposed model.

Conclusions and Future Recommendations

Improved comprehension of the information contained in images is facilitated by the detection and extraction of textual content. It was observed that numerous computer vision-based applications may use

the retrieved text as input. It was difficult to retrieve text from documents and pictures of natural environments. In this study, an explainable combination of NN and fuzzy logic was developed as a method for text extraction from multilingual documents. The goal of this endeavor was to create intelligent systems that could automatically categorize texts in multiple languages. Neural networks and fuzzy output systems were used to solve the challenge of information object recognition. The proposed model will be implemented using a variety of machine learning approaches in the future.

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