ANALYSIS OF SOFT COMPUTING TECHNIQUES FOR IMAGE CLASSIFICATION

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Abstract: Soft computing techniques are the family of problem-solving techniques widely used in real-world problems to deal with imprecision, approximation, tractability, robustness, and low-cost solution. With the development of soft computing techniques, image classification problem also increases the interest of researchers. Various issues and challenges are persisting in applying these techniques in image classification. This paper presents analysis of soft computing techniques for image classification problems.

Index Terms - **Soft Computing, Image Classification, Multi-Layer Perceptron, CNN, DNN.**

I. INTRODUCTION

The Soft computing term is first coined by LA Zadeh in early 1990s, which is emerging family of problem-solving techniques which are tolerant of imprecision, approximation, tractability, robustness, and low-cost solution. These techniques mimic the ability of the human mind to reason and learn in an environment of imprecision, approximation, and uncertainty. The human mind can categorize the object into different classes based on their visual features. Classification problems also can solve by using computers (machines). Problem-solving techniques must be tolerant of the variations of input images and output class. For this, several researchers and scientists have developed various soft computing techniques for image classification.

This paper represents a review of various soft computing techniques for image classification and analysis of these techniques. Based on an analysis of these techniques, we found that many issues persisting due to their limitations. These persisting issues motivate us to take as a challenge to analyse and high lightened the problems for the interest of researchers to handle the Image classification problem.

This paper consists of four sections: review work of soft computing techniques for image classification presented in Section 2. Analysis of the soft computing techniques for image classification have been given in Section 3. Finally, Section 4 concludes the paper.

II. REVIEW WORK

With the emergence of soft computing techniques [1] [2], it became the subject of interest of the researcher. To solve the image classifications problem, which mainly focused on extracting the feature and descriptions of elements of images, like corner, line, edge, shape, and texture using soft computing techniques such as fuzzy logic, probabilistic reasoning, genetic algorithm, and neural network. These techniques comprise two categories; category first is approximate reasoning: is a process by which a possibly imprecise conclusion has deduced from a set of imprecise premises, whereas category second: is functional approximation and optimization that approximate and optimize the function among the defined class of knowledge. Fuzzy logic and probabilistic reasoning belong to the Approximate reasoning category, while genetic algorithm and neural network belong to the functional approximation and optimization category.

Soft computing techniques that belong to approximate reasoning is the Fuzzy logic introduced and provides a fuzzy rule generation language with syntax and semantics, in which qualitative knowledge about the problem translations solved by LA Zadeh [3] [4] [5]. In 1975 Mamdani et al. first proposes the Fuzzy controllers and commercially applied them for automated controlling in the industry [6]. The uncertainty of the actual value of a membership function has been addressed Type-2 fuzzy set by Liang et al. [7]. Fuzzy logic their different variants like Type 2 fuzzy, fuzzy C means algorithm has widely used in image classification. Nedeljkovic et al. presented fuzzy logic-based image classification, a priori knowledge about spectral information for the certain land cover classes are used to classify SPOT images in the fuzzy logic classification procedure [8]. The fuzzy rules have been generated based on the linguistic description of the input and output variables. A fuzzy inference system has been defined using input, output variables and

generates fuzzy rules. Further, the fuzzy inference system has been used for image classifications. Jabri et al. presented object-based image analysis and fuzzy rules generation techniques for the classification of very high-resolution urban satellite images into specific classes such as road, building, vegetation, etc. The separate fuzzy rules have been generated for each output class on parameters of image and object-based image analysis [8]. Type 2 fuzzy sets are the extension of original fuzzy sets. Mitchell et al. proposed a type 2 similarity measure for type 2 fuzzy sets and show that type 2 fuzzy sets provide a natural language for formulating classification problems in pattern recognition [10]. The type 2 fuzzy logic in different real-world applications review by Melin et al. [11]. Whereas, Fuzzy c mean algorithms are used for clustering the input data and for image segmentation have been inspired from Markov random field and less sensitive to noise modified by Mohamed et al. [12]. His image segmentation process improves the performance of image classification. A semi-supervised interval type 2 fuzzy C means clustering algorithm that exploits local spatial information between pixel and its neighbouring pixels to compute the membership degree proposed by Ngo et al. [13]. The membership degree of each pixel classifies the pixels into corresponding output classes. Therefore, this soft computing technique (fuzzy logic) is mainly used for image classification and clustering of image data. But it is unable to extract the features from input image data; it requires an additional computation for feature extraction which is overhead on fuzzy logic techniques. This overhead made this technique less efficient for image classification.

In literature, a soft computing technique that belongs to the approximate reasoning category is probabilistic reasoning, based on probability (1814) and evidence theory (1736). That is a method for representing knowledge where the probability concept is applied to indicate the uncertainty in knowledge. The Bayesian probability is used to improve classification relation and mapping from input data to output class. K-NN, Naive Bayes classifier is simple, fast clustering and classification algorithms that perform unsupervised classification in image classification models [14] [15]. Hilton et al. [16] proposed a deep belief network that uses Dempster-Shafer's theory of belief for training input data in an unsupervised manner. Therefore, Probabilistic reasoning is used for the classification and clustering of image data. It is also unable to handle the feature extraction task of image classification.

Since, another soft computing technique, Genetic algorithms provide a way to perform a random global search in a solution space. In this space, a population of candidate solutions, encoded as chromosomes, is evaluated by a fitness function in terms of its performance. The best candidates evolve and pass some of their characteristics to their off-springs. This algorithm performs the task of optimization in image classification to find the optimized set of feature sets [17]. In literature, hybrid models use the genetic algorithm for adaptive learning and tuning the other soft computing models [18, 19]. In the Genetic fuzzy model [20], genetic algorithms are used to optimize fuzzy relationship rules for a better selection of fuzzy rules. The role of Genetic algorithms image classification models is to optimize the feature sets, selection of initial weights in the neural networks-based model, optimize the fuzzy rules in the fuzzy-based model. But it is unable to perform the classification task which makes this technique only assisting to image classification task.

To overcome the overhead of feature extraction classification, the Neural Network model tries to replicate only the most basic functions of the brain. It provides a supervised learning algorithm that performs local optimization during learning by using a training set based on a backpropagation type of algorithm that performs fine-granule local optimization and improves the performances of Multilayer Perceptron (MLP). Radial basis function (RBF) based neural networks have the same architecture but use different neural activation functions. Neural Networks such as MLP and RBF widely used since the advent of neural networks in real-world computer vision applications [21-23]. A new feed-forward algorithm for the training of neural networks was introduced by G. B Huang [24]. That is extreme Learning Machine (ELM) which provides real-time training of NNs. This training algorithm uses single-time computation which is the opposite of the backpropagation algorithm, which uses the iterative method.

With the introduction of Deep learning algorithms and growth in high computation power, swallow NNs become Deeper and more complex. Deep learning-based model Convolutional Neural Network (CNN), Deep Neural Network (DNN) competes with human accuracy in many areas. CNN is a complete model for image classification which automatically learns low to high features and classifies them into output classes. While DNN, with its deep architecture, provides an image classification model to learn higher abstraction to lower abstraction of training data in its multiple deep layers [25,26]. To exploits, the feature learning ability of CNN, various hybrid models such as CNN-ELM, CNN-RNN, CNN-RF, etc are also developed. CNN-ELM classifier proposed by Zeng et al. for traffic sign recognition and achieved human-level accuracy [27].

The Next section provides the analysis of soft computing techniques for image classification.

III. ANALYSIS OF SOFT COMPUTING TECHNIQUES FOR IMAGE CLASSIFICATION

Based on literature review, we have found that soft computing-based image classification methods are uses to solve the complete or part of an image classification problem.

Soft Computing Techniques	Methods	Role in image classification	Application	Reference
Fuzzy Logic	Fuzzy logic	Classification	Satellite image classification	Nedeljkovic et al. [8]
	Fuzzy logic	Classification	Satellite image classification	Jabri et al. [9]
	Type 2 Fuzzy logic	Classification	Radiographic image classification	Mitchell et al. [10]
	Type 2 Fuzzy logic	Clustering, Classification	Land cover classification	Melin et al. [11]
	Fuzzy C mean	Segmentation	Medical imaging	Mohamed et al. [12]
	Type 2 Fuzzy C mean	Clustering, Segmentation	Satellite image classification	Ngo et al. [13]
Probabilistic Reasoning	LMS algorithm with naïve bayes	Classification	Halftone image classification	Liu et al. [14]
	Local naïve Bayes nearest neighbour	Classification	General image classification	McCann et al. [15]
	DBN	Classification	General image classification	Hinton et al. [16]
Genetic Algorithm	Genetic algorithm	Feature selection	General image classification	Lin et al. [17]
	GA and PSO	Feature selection, optimization	Remote sensing imaging	Ghamisi et al. [18]
	Genetic algorithm and SVM	Feature selection	Satellite image classification	Li et al. [19]
	Genetic fuzzy logic	Fuzzy rule optimization	Land cover classification	Stavrakoudis et al. [20]
Neural network	ANN	Classification	Land cover classification	Kanellopoulos et al. [21]
	MLP and RBF	Classification	Agricultural crop classification	Foody et al. [22]
	LeNet	Feature learning, Classification	Handwritten digit classification	Lecun et al. [23]
	ELM	Classification	General image classification	Huang et al. [24]
	CNN	Feature learning, Classification	General image classification	Krizhevsky et al. [25]
	DNN	Feature learning, Classification	General image classification	Ciresan et al. [26]
	CNN-ELM	Feature learning, Classification	Traffic sign classification	Zeng et al. [27]

Table 1. Analysis of Soft Computing Techniques and Their Roles in Image Classification

In the paper, we have taken four soft computing techniques for analysis purposes, proposed by various researchers, and analysed them based on subjective evaluating parameters (roles/tasks) such as classification, clustering, segmentation, feature extraction, feature learning, and optimization, which tabulated in Table 1. Here, based on Table 1 it is clear that

- Fuzzy logic-based methods perform the segmentation, clustering, and classification task. The main work of these methods is to generate the fuzzy relation rules for input features of the image and output class of the image,
- the probabilistic reasoning-based methods based on probabilistic theory and belief theory perform the task of classification in image classification, in both supervised and unsupervised manners.
- Genetic algorithm-based methods perform the task of optimization of features (feature selection, feature optimization).
- Neural network-based methods perform the feature learning (automated feature extraction) and classification task. It learns from the examples of images (training dataset). The main work of these methods is to learn a mapping between the input images and their out classes.

Based on the analysis of Table 1, it is clear that soft computing techniques play a major role in image classification.

After analysis of soft computing techniques presented in table-1 and various methods tabulated in Table 1, some image classification models based on the issue, such as integration of classifiers, unknown (adverse) images are taken into interest by various researchers. The model-based issue arises from various aspects of real-world image classification problems, which leads the specialized image classification domain to the general image classification domain. Therefore, it is not possible to resolve all issues in a single soft computing technique. These are challenging tasks for researchers to develop a soft computing technique for image classification which resolve all image classification problems.

IV. CONCLUSION

In this paper four soft computing techniques and comparative analysis of various methods has been presented. Analysis shows that each problem-solving methods of soft computing have a role in image classification. But the neural network-based methods provide the complete solution of feature learning and classification, so it is more effective.

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