Towards Rough Neural Computing Based on Rough Membership Functions: Theory and Application

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Abstract. This paper introduces a neural network architecture based on rough sets and rough membership functions. The neurons of such networks instantiate approximate reasoning in assessing knowledge gleaned from input data. Each neuron constructs upper and lower approximations as an aid to classifying inputs. Rough neuron output has various forms. In this paper, rough neuron output results from the application of a rough membership function. A brief introduction to the basic concepts underlying rough membership neural networks is given. An application of rough neural computing is briefly considered in classifying the waveforms of power system faults. Experimental results with rough neural classification of waveforms are also given.

1 Introduction

A form of rough neural computing based on based on rough sets, rough membership functions, and decision rules is introduced in this paper. Rough sets were introduced by Pawlak [1], and elaborated in [2]-[3]. Rough membership functions were introduced by Pawlak and Skowron [4]. Studies of neural networks in context of rough sets are extensive [5]-[12]. This paper considers the design and application of neural networks with two types of rough neurons: approximation neurons and decider neurons. The term *rough neuron* was introduced in 1996 [5]. In its original form, a rough neuron was defined relative to upper and lower bounds and inputs were assessed relative to boundary values. More recent work considers rough neural networks (rNNs) with neurons, which construct rough sets and output the degree of accuracy of an approximation [10]-[11], which is based on an earlier study [9]. The study of rough neurons is part of a growing number of papers on neural networks based on rough sets. Rough-fuzzy multilayer perceptrons (MLPs) in knowledge encoding and classification were introduced in [12]. Rough-fuzzy neural networks have recently been also used in classifying the waveforms of power system faults [10]. Purely rough membership function neural networks (rmfNNs) were introduced in [11] in the context of rough sets and the recent introduction of rough membership functions [4]. This paper considers the design of rough neural networks based on

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rough membership functions, and hence this form of network is called a rough membership neural network (rmNN). Preliminary computations in a rmNN are carried out with a layer of approximation neurons, which construct rough sets and where the output of each approximation neuron is computed with a rough membership function. The values produced by a layer of approximation neurons are used to construct a condition vector. Each new condition vector provides a stimulus for a decider neuron in the output layer of a rmNN. A decider neuron enforces rules derived from decision tables based on rough set theory. A decision table reflects our knowledge of the world at a given time. This knowledge is represented by condition vectors and corresponding decisions. Information granules in the form of rules are extracted from decision tables using rough set methods. Discovery of decider neuron rules stems from an application of the rule derivation method given in [13]-[14]. This characterization of a decider neuron is based on the identification of information granules based on decision rules [15]. Each time a decider neuron is stimulated by a new condition vector constructed by the approximation neuron layer, it searches for the closest fit between each new condition vector and existing condition vectors extracted from a decision table. Decider neurons are akin to what are known as logic neurons described in [16].

2 Rough Membership Functions

A brief introduction to the basic concepts underlying the construction of rough membership neural networks is given in this section. A rough membership function (rm function) makes it possible to measure the degree that any specified object with given attribute values belongs to a given set X [4], [21]. A rm function μ_X^B is defined relative to a set of attributes $B \subseteq A$ in information system S = (U, A) and a given set of objects X. The equivalence class $[x]_B$ induces a partition of the universe. Let $B \subseteq A$, and let X be a set of observations of interest. The degree of overlap between X and $[x]_B$ containing x can be quantified with the rough membership function:

$$\mu_X^B : U \to [0,1] \text{ defined by } \mu_X^B(x) = \frac{\left|[x]_B \cap X\right|}{\left|[x]_B\right|}$$

3 Design of Rough Neural Networks

Neural networks are collections of massively parallel computation units called neurons. A neuron is a processing element in a neural network.

3.1 Design of Rough Neurons

Typically, a neuron y maps its weighted inputs from $\mathbf{R}^n$ to [0, 1] [16]. Let T be a decision table (X, A, {d}) used to construct $\underline{B}X$, $\overline{B}X$, and let $X \subseteq Y$. A selection of