3 INTELLIGENT FUSION AND TRANSFORMATION SYSTEMS

3.1 INTRODUCTION

In recent times, research efforts have been directed towards hybridization of various intelligent methodologies in order to solve complex industrial problems. At the same time these research efforts have been undertaken to develop a better understanding of the human information processing system. Today, one can find a number of applications involving hybridization of intelligent methodologies like knowledge based systems, fuzzy systems, genetic algorithms, and case based reasoning with artificial neural networks. The central methodology of many hybrid systems has been artificial neural networks. In fact, 2/3rd of the applications involving intelligent hybrid systems use neural networks. Broadly, in these applications neural networks are either used as the primary problem solving entity, or are used in conjunction with other intelligent methodology/ies which have a distinct and separate role to play in the problem solving process. The former are categorized as fusion and/or transformation based approaches, and the later are categorized as combination approaches. However, fusion and/or transformation based approaches center around not only neural networks but also center around the other other methodology, namely,
genetic algorithms. Similarly, the combination approaches can involve intelligent methodologies other than neural networks also. The goal of this chapter is to provide an overview to the reader about fusion and transformation based synergies with neural network and genetic algorithms as the primary problem solving entities. In this direction, this chapter looks at the neuro-symbolic systems, neuro-fuzzy systems, genetic-neuro systems, and genetic-fuzzy systems.

### 3.2 FUSION AND TRANSFORMATION

The difference between fusion and transformation can be understood based on the tasks and constraints associated with these concepts. Fusion occurs in tasks primarily where the task complexity is high, and adaptation, performance and optimization are important to the solution of the problem. Transformation Fusion implies that it is possible to fuse the knowledge and/or reasoning from one intelligent methodology to another. The fusion process generally involves hard wiring representation of one intelligent methodology into another. That is, the transition from one representation to another does not occur naturally. In fusion based systems the task and constraints (e.g. adaptation, optimization and performance) are generally satisfied within one representation or methodology (e.g. artificial neural network). In fusion based systems the solution to a task or problem is realized in the framework of one intelligent methodology (e.g. artificial neural network). (e.g. fusion of fuzzy knowledge and inference in a neural network).

Transformation on the other hand, occurs in situations where knowledge required to accomplish the task is not available and one intelligent methodology depends upon another intelligent methodology for its reasoning or processing (e.g. extraction of rules from a neural networks so that the rule-based system can reason with the extracted rules). Transformation systems also generally use numerical data as a starting point for the solving the problem, whereas fusion systems generally use symbolic or fuzzified data to start with for fusion purposes. In transformation systems the task constraints are satisfied through two representations or two methodologies (e.g. one representation using artificial neural network used for learning the rules and the other representation using extracted rules for reasoning).

Transformation can also take place in situations where transformation occurs in the form of optimization. It requires transformation of an optimized representation from one methodology to another (e.g. rule refinement - extraction of optimized rules from an optimized neuro-symbolic network). Such systems are called fusion and transformation systems where unoptimized representation A is fused into representation B and then optimized representation A is extracted from optimized representation B.
properties of the backpropagation algorithm have also been effectively used to fine tune input membership functions of the fuzzy inputs.

3.4.1.3 Implementation of Fuzzy Logic Operations in Neural Networks. In conventional, supervised backpropagation neural network the nodes usually employ the weighted-sum function to compute the activation of an output node. In certain neuro-fuzzy systems the weighted-sum function is replaced by fuzzy logic based min-max operations (Watnabe et al. 1990; Hayashi et al. 1992; Pedrycz et al. 1993; Kwan et al. 1994). The multiplication part of the weighted-sum function is replaced by the min operation and the addition part of the weighted-sum function is replaced by the max operation (Watnabe et al. 1990). The structure of such a logical neuron is shown in Figure 3.9. The activation of the neuron is determined as follows:

\[ y = \max((\min(w_1, x_1), (\min(w_2, x_2)), \ldots, (\min(w_n, x_m)))) \]

\[ z = y - th, \text{ where } th \text{ is the threshold value for activation of the neuron} \]

The desired output value \( d \) is used to compute the error to be propagated back into the network.

The use of min-max logical neurons can result in enhancing the speed of operation (i.e reduced computation time) of the neural network and robustness in separability of the input patterns (Watnabe 1990). Maeda et al. (1993) have developed a Fuzzy Logic Inference Procedure network (FLIP-net) for a road tunnel ventilation control system. The backpropagation learning technique is used for tuning the shapes of membership functions. The logical relationships between fuzzy rules and membership functions, however remain the same. This feature facilitates adding and modification of fuzzy rules and membership functions by the developer.

A point to be noted here is that the use of logical neurons can also result in convergence problems in a gradient descent based learning method because of discontinuous derivatives of some logical functions (Pedrycz 1991).

3.4.2 Bottom Up Neuro-Fuzzy Fusion Systems

As outlined by Takagi et al. (1992a, 92b) the motivation behind the bottom up fusion of neural networks and fuzzy systems is to take advantage of the learning properties of artificial neural networks. As shown in Figure 3.1, bottom-up neuro-fuzzy fusion systems use the continuous medium, i.e., numerical data in the form of input-output data pairs or simply input data to describe the problem.

Bottom up neuro-fuzzy fusion systems can be categorized into systems which:
works. On the other hand, bottom up neuro-fuzzy transformation systems involve learning fuzzy clusters, learning fuzzy membership functions, and learning fuzzy if-then rules.

Genetic algorithms can be seen as an alternative optimizing technique to neural networks. Genetic algorithms based fusion and transformation systems are largely used for optimization problems. Intelligent genetic-fuzzy systems are used for automating and optimizing the design of fuzzy systems. Genetic-neuro or genetic-neuro-fuzzy system as described in this chapter are used for optimizing the connection weights, neural network structure or topology, and input data set to a neural network. In the next chapter combination approaches are discussed which involve all the four intelligent methodologies are discussed.

Notes

1. The terms artificial neural networks and neural networks have been used interchangeably throughout the book.

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