4 Retracted Chapter: Adaptive Resonance Theory Networks

4.1 Introduction

The Adaptive Resonance Theory (ART) model is one of the triumphs of modern neural network theory developed to overcome the stability-plasticity dilemma [1], [2], [37], [38], [47]. When someone has to add more to what they have already learnt, there is no need for complete retraining as there is no chance of one forgetting all that he has already learnt. But such is not the case in electronic networks as a catastrophic forgetting may occur if one tries to add more patterns to a stable trained network. There is a trade-off between the stability and ability to learn new data. This is known as the stability plasticity dilemma.

The ART network produces a stable network that can learn new data. The main idea behind this is to spare some of the output units for new patterns. When the input and a stored pattern are sufficiently similar, they are said to resonate. When there is not sufficient similarity, a new class of patterns is formed utilizing the unused output units. There is no response from the network when all output units are used.

Several versions of ART networks have been implemented: ART1, ART2, ART3 and ARTMAP [15], [19], [76]. ART1 can stably learn to categorize binary input patterns presented in an arbitrary order. ART2 does the same with either analog or binary input patterns whereas ART3 can carry out parallel search, or hypothesis testing, or distributed recognition codes in a multilevel network hierarchy. The ARTMAP in turn can rapidly self-organize stable categorical mappings between n-dimensional inputs and m-dimensional output vectors.

The fuzzy ART model [16], [17], [32], [41], [119] approximates surfaces in a fuzzy cube of high dimension. Each pattern is considered as a discrete fuzzy set. This ART system uses the degree of subsethood to control how well fuzzy patterns match. The system covers the decision surface with hyper boxes just as a feed forward fuzzy system covers a function’s graph with rule patches. The growth in the dimension of the space results in an explosion. The fuzzy ART model uses subsethood to control the fineness of the hyper box cover in a fixed fuzzy cube. This result blends the core concepts of fuzzy cubes and feedback neural networks in a novel and powerful architecture.

4.2 ART Network

Grossberg [14], [18] and his associates have worked for nearly 20 years on theories to explain human cognition in terms of neural network operations. Their research has culminated in a model called ART. In a competitive learning scheme, there is no guarantee that the clusters formed will be stable unless the learning rate gradually approaches zero with iteration. When this happens, the network loses its plasticity. The ART1 network overcomes this dilemma. In ART, a weight vector (prototype of a category) is adapted only when the input is sufficiently similar to that of the prototype, that is when the input and a prototype resonate.

When an input is not sufficiently similar to any prototype, a new category is formed using the input as the prototype. This condition is checked using a vigilance parameter. The ART network gets its name from the particular way in which learning and recall interplay in the network. In physics, resonance occurs when a small-amplitude vibration of the proper frequency causes a large-amplitude vibration in an electrical or mechanical system.

In ART network, information in the form of processing element outputs, reverberates back and forth between layers. If the proper pattern develops, a stable oscillation ensues, which is the neural network equivalent of resonance. During resonant period, learning or adaptation can occur. Before the network has achieved a resonant state, no learning takes place, because the time required for changes in the processing element weights is much longer than the time that it takes the network to achieve resonance.

4.2.1 Resonant State

A resonant state can be attained in one of the two ways. If the network has learned previously to recognize an input vector, then when that input vector is presented, a resonant state will be achieved quickly. During resonance, the adaptation process will reinforce the memory of the stored pattern. If the input vector is not immediately recognized, the network will rapidly search through its stored patterns looking for a match. If there is no match to be found, the network will enter a resonant state whereupon the new pattern will be stored for the first time. Thus the network responds quickly to previously learned data and yet remains able to learn when novel data are presented.

4.2.2 The STM and LTM Traces

The ART model comprises of two subsystems namely the attention subsystem and the orienting subsystem. Familiar or previously learned patterns are processed within the attentional subsystem. This subsystem establishes precise internal representations to familiar events. By itself this subsystem is unable to simultaneously maintain stable representations of familiar categories and create new categories for the unfamiliar patterns.

The second subsystem fills this inadequacy by resetting the attentional subsystem when unfamiliar events occur. This orienting subsystem is essential for determining whether a new pattern is familiar and has a recognition code or unfamiliar and in need for a new recognition code. Patterns of activity that develop over the nodes in the two