Glossary

This glossary contains terms important to the study of computational intelligence, neural networks, fuzzy logic, and evolutionary computation. In many cases, these terms have been absorbed from the related disciplines of engineering, mathematics, biology, physics, statistics, and other scientific or business fields.

Activation function (activation rule) An algorithm for computing the activation value of a processing element as a function of its inputs. The activation function is sometimes the weighted sum of the inputs (inner product of the weight vector and the input vector), followed by a threshold or squashing function. More often, it comprises only the threshold or squashing function.

Activation state The collective activation values of a group of processing elements in a neural network.

Activation value The output value of a processing element. Values may be continuous or discrete. Continuous values may be bounded to some interval. Discrete values may be restricted to some small set of values.

Adaline Adaptive linear element, a processing element implementing a weighted sum of inputs. It was developed by Bernard Widrow.

Adaptation Any process whereby a structure is progressively modified to give better performance in its environment (Holland 1992). *Dynamic adaptation* is the ability of a system to adapt in a changing (dynamic) environment.

Adaptive resonance theory Adaptive resonance theory was developed by Grossberg as a theory of human cognitive information processing. It is implemented by binary and analog versions of neural networks.

Algorithm A step-by-step procedure for finding the solution to a problem (Chapman 2000). It is usually readable and understandable by a human.

Allele An individual value a gene may assume.

Ambiguity See *Fuzziness*.

Antecedent The *if* part of an if-then rule. Also called the *precondition* or *assumption*.

Approximate reasoning See *fuzzy inference*.

Architecture The specification of the layers, number of processing elements per layer, and interconnections between the layers in a neural network.

Arity The number of arguments required by a function.

Artificial intelligence (AI) The study of how to make computers do things at which, at the moment, people are better (IEEE Neural Networks Council 1996). AI is concerned with intelligent behavior in artifacts. Intelligent behavior, in turn, involves perception, reasoning, learning, communicating, and acting in complex environments (Nilsson 1998).

Artificial neural network (ANN) An analysis paradigm that is roughly modeled after the massively parallel structure of the brain. It simulates a highly interconnected, parallel computational structure with many relatively simple individual processing elements (PEs).

Associative memory Memory with the property to recall an entire pattern given a partial or noisy pattern.

Autoassociative network A neural network that uses single patterns rather than pattern pairs.

Axon The sending fiber of a neuron. The action potential of the neuron cell body is transmitted along the axon, from which it is received via synapses by the dendrites of other neurons.

Back-propagation A learning rule for multilayer feedforward networks in which weights are adjusted by backward propagation of the error signal from the outputs to the inputs. It uses gradient descent learning.

Batch training (epoch training) A procedure for training neural networks in which weights are adjusted after each epoch. See *Interactive training*.

Bias An additional node in a neural network with a constant activation value. The bias can be connected to any number of layers in a network, via fixed or variable weighted connections, which act as offsets to the processing elements.

Building blocks In a genetic algorithm, this term generally refers to compact (short) schemata that are part of highly fit individuals, and which, with high probability, appear in ever-increasing numbers in future generations.

Cell See *Neuron*.

Cellular automaton (CA) A very simple virtual machine that can result in complex, even lifelike, behavior (Kennedy, Eberhart, and Shi 2001).

Chromosome In evolutionary computation, a chromosome is a string of symbols, bits, and/or real numbers that represents one possible solution in a population of solutions.

Classifier system A system that takes (a set of) inputs and produces (a set of) outputs that indicate some classification of the inputs. An example might take inputs from sensors in a chemical plant and classify them in terms of: "running OK," "needs more water," "needs less water," and "emergency." (IEEE Neural Networks Council 1996)

Closure property In genetic programming, for the closure property to be satisfied, each function must be able to successfully operate on any function in the function set and on any value of any data type assumable by a member of the terminal set.

Codebook vector An input pattern that generates a maximum or nearly maximum activation value for a given output processing element (classification) of a neural network.

Competitive learning An unsupervised learning scheme in which processing elements compete for the right to respond to a given subset of inputs. The response of a processing element to an input pattern tends to inhibit other units. After learning, processing elements become feature detectors. See *Lateral inhibition*.

Complexity The interaction of many parts of a system, giving rise to behaviors and/or properties that are not found in the individual elements of the system (Kennedy, Eberhart, and Shi 2001).

Computational intelligence Comprises practical adaptation concepts, paradigms, algorithms, and implementations that enable or facilitate appropriate actions (intelligent behavior) in complex and changing environments.

Confusion matrix A matrix in which the man-made (rows) and the machine-made (columns) classifications per class are entered. A perfect classifier has only the diagonal populated. Errors appear in nondiagonal positions. The confusion matrix is an efficient way to observe the separability between classes (Principe, Euliano, and Lefebvre 2000).

Connection (link) A unidirectional information pathway between processing elements in a neural network.

Connection strength (weight) The strength of a connection between two processing elements, which determines the net effect of one processing element on the other. Connections can have a positive (excitatory), zero, or negative (inhibitory) effect.

Connectionism Generally related to neural networks. Refers to highly distributed systems in which computations are based on the inter-PE weights (connections).

Consequent The *then* part of an if–then rule. Also called the *conclusion*.

Constriction factor A coefficient used in particle swarms to ensure convergence of the particle swarm optimization algorithm.

Content addressable memory See *Associative memory.*

Converged (as used in evolutionary computation) A gene is said to have converged when a high percentage of the chromosomes in the population all contain the same allele for that gene. In some circumstances, a population can be said to have converged when all genes have converged. The term is sometimes used (or misused) informally to indicate that an evolutionary algorithm population has not found an improved solution in a large number of generations.

Core In a fuzzy set, the crisp set of objects that have a membership of 1 in the fuzzy set. It can also be defined as the alpha-cut when alpha = 1 (IEEE Neural Networks Council 1995).

Crisp logic The 0 and 1 logic used by digital computers. Sometimes called Aristotelian logic. Something is either *true* or *false*, *on* or *off*. Truth is all or nothing, absolutely true or absolutely false, with no middle ground possible.

Crossover In genetic algorithms, formation of a new chromosome when a reproduction operator combines parts of each of two "parent" chromosomes. The simplest form is single-point crossover, in which an arbitrary point in the chromosome is picked. All the information from parent A is copied from the startup to the crossover point; then all the information from parent B is copied from the crossover point to the end of the chromosome. The new chromosome thus gets the head of one parent's chromosome combined with the tail of the other. Variations exist that use more than one crossover point or combine information from parents in other ways. (IEEE Neural Networks Council 1996)

Crossover point In fuzzy logic, the lowest membership point between two adjacent membership functions (linguistic terms) over a domain.

Crossover rate In a genetic algorithm, the probability that given two parent chromosomes, the crossover process will occur.

Deception The condition where the combination of good building blocks leads to reduced fitness rather than increased fitness. Proposed by Goldberg (1989) as a reason for the failure of GAs on many tasks. (IEEE Neural Networks Council 1996)

Defuzzification A fuzzy set maps an object into a membership value. The inverse of this process takes a fuzzy set, a set of fuzzy sets, or some system that has fuzzy uncertainty, and produces a single crisp object that is most representative in some well-defined

mathematical sense of the set, sets, or system. Several methods are used for defuzzification; most involve computing some type of a mean or mode of a fuzzy set, or sets, or system (such as center-of-area, mean-of-maximum, or height-based methods). (after IEEE Neural Networks Council 1995)

Degree of membership See *membership function*.

Delta rule See *Widrow–Hoff rule*.

Dendrite The receiving fibers of a neuron. Dendrites receive action potentials via synapses from other neurons or from the environment.

Discrete recombination In evolution strategies, an operation that comprises selection of parameter values from either of two parents.

Distributed representation An information representation scheme in which entities are represented by patterns of activity, distributed over many processing elements. Long-term memory is represented by connection weights. Short-term memory is represented in recurrent networks by the activation states of processing elements. Stored knowledge cannot be isolated to a single location as in the Von Neumann computer. The robustness of neural networks is due to this property. See *parallel distributed processing*.

Dot-product See *inner product*.

Elitist strategy In a genetic algorithm, ensuring that the individual chromosome with the highest fitness is always copied into the next generation.

Entropy The tendency of systems to lose energy and order and to settle to more homogeneous states (Kennedy, Eberhart, and Shi 2001).

Epistasis In evolutionary computation, any kind of strong interaction among genes, not just masking effects. A possible definition is the interaction between different genes in a chromosome. It is the extent to which the contribution to fitness of one gene depends on the values of other genes. Problems with little or no epistasis are trivial to solve (hill-climbing is sufficient). But highly epistatic problems are difficult to solve, even for GAs. High epistasis means that building blocks cannot form, and there will be deception. (IEEE Neural Networks Council 1996)

Epoch The presentation of a complete set of patterns to a neural network.

Epoch training See *batch training*.

Error term (**error signal**) A measure of the difference between the observed state and the desired state of a processing element.

Euclidean distance The geometric distance between two points, given by the square root of the sum of the squared differences between vector components.

Euclidean normalization The normalization of a vector to unit length, obtained by dividing each component of the vector by the vector length.

Evolution The process of change that is assured given a reproductive population in which there are varieties of individuals, with some varieties being heritable, of which some varieties differ in fitness (reproductive success). (IEEE Neural Networks Council 1996)

Evolution strategies A type of evolutionary algorithm developed in the early 1960s in Germany. It employs real-coded parameters and, in its original form, relied on mutation as the search operator and a population size of one. Since then it has evolved to share many features with genetic algorithms. (IEEE Neural Networks Council 1996)

Evolution window In evolution strategies, the step-band size, or window, within which mutation operations result in fitness improvement.

Evolutionary computation (EC) Machine learning optimization and classification paradigms roughly based on mechanisms of evolution such as biological genetics and natural selection. The evolutionary computation field includes genetic algorithms, evolutionary programming, genetic programming, evolution strategies, and particle swarm optimization.

Evolutionary programming An evolutionary algorithm developed in the mid-1960s. It is a stochastic optimization strategy, which is similar to genetic algorithms but dispenses with both "genomic" representations and crossover as a reproduction operator. (IEEE Neural Networks Council 1996)

Exploitation When traversing a search space, the process of using information gathered from previously visited points in the search space to determine which places might be profitable to visit next. An example is hill-climbing, which investigates adjacent points in the search space and moves in the direction giving the greatest increase in fitness. Exploitation techniques are good at finding local maxima. (IEEE Neural Networks Council 1996)

Exploration The process of visiting entirely new regions of a search space to see if anything promising may be found there. Unlike exploitation, exploration involves leaps into the unknown. Problems that have many local maxima can sometimes only be solved by this sort of random search. (IEEE Neural Networks Council 1996)

Fan-in The number of connections to the input of a processing element or unit.

Fan-out The number of connections from the output of a processing element or unit.

Feedback network (recurrent network) A network with feedback paths. Feedback can occur within layers or between layers. The current activation state of a layer is a function of the previous activation state and the current inputs.

Feedforward network A network ordered into layers with no feedback paths. The ordering is from input (lowest), through one or more hidden layers, to the output layer (highest).The outputs of a given layer are connected to higher layers only, and its inputs originate from lower layers only.

Finite state machine A transducer that can be stimulated by a finite alphabet of input symbols, can respond in a finite alphabet of output signals, and possesses some finite number of different internal states (Fogel 1991).

Fitness A value assigned to an individual (candidate solution) that reflects how well the individual solves the problem being addressed, usually by an evolutionary algorithm.

Full approach In genetic programming, each limb of the program tree extends for the maximum allowed depth.

Function An expression that accepts one or more input values and calculates a single result from them.

Function space Contains the ranges of results of functions (Kennedy, Eberhart, and Shi 2001).

Fuzzification Combining the antecedent fuzzy sets, that is, the sets on the "if-" side of a fuzzy rule, using fuzzy operators.

Fuzziness Refers to nonstatistical imprecision and vagueness in information and data.