

Glossary

The glossary entries are coded using the following abbreviations:

- es = expert systems
- fl = fuzzy logic
- nn = neural networks
- ec = evolutionary computation
- dm = data mining
- ke = knowledge engineering

Action potential

An output signal (also called *nerve impulse*) of a biological neuron that does not lose strength over long distances. When an action potential occurs, the neuron is said to 'fire an impulse'. [nn]

Activation function

A mathematical function that maps the net input of a **neuron** to its output. Commonly used activation functions are: **step**, **sign**, **linear** and **sigmoid**. Also referred to as **Transfer function**. [nn]

Adaptive learning rate

A **learning rate** adjusted according to the change of **error** during **training**. If the error at the current **epoch** exceeds the previous value by more than a predefined ratio, the learning rate is decreased. However, if the error is less than the previous one, the learning rate is increased. The use of an adaptive learning rate accelerates **learning** in a **multilayer perceptron**. [nn]

Aggregate set

A fuzzy set obtained through **aggregation**. [fl]

Aggregation

The third step in **fuzzy inference**; the process of combining **clipped** or **scaled** consequent **membership functions** of all **fuzzy rules** into a single **fuzzy set** for each output variable. [fl]

Algorithm

A set of step-by-step instructions for solving a problem.

AND

A logical operator; when used in a **production rule**, it implies that all antecedents joined with AND must be true for the rule **consequent** to be true. [es]

Antecedent

A conditional statement in the IF part of a **rule**. Also referred to as **Premise**. [es]

a-part-of

An **arc** (also known as ‘**part-whole**’) that associates subclasses representing components with a superclass representing the whole. For example, an engine is *a-part-of* a car. [es]

Approximate reasoning

Reasoning that does not require a precise matching between the IF part of a **production rule** with the **data** in the **database**. [es]

Arc

A directed labelled link between nodes in a **semantic network** that indicates the nature of the connection between adjacent nodes. The most common arcs are **is-a** and **a-part-of**. [es]

Architecture

see **Topology**. [nn]

Artificial neural network (ANN)

An information-processing paradigm inspired by the structure and functions of the human brain. An ANN consists of a number of simple and highly interconnected processors, called **neurons**, which are analogous to the biological neurons in the brain. The neurons are connected by weighted links that pass signals from one neuron to another. While in a biological neural network, learning involves adjustments to the **synapses**, ANNs learn through repeated adjustments of the **weights**. These weights store the **knowledge** needed to solve specific problems. [nn]

Artificial intelligence (AI)

The field of computer science concerned with developing machines that behave in a way that would be considered intelligent if observed in humans.

Assertion

A **fact** derived during **reasoning**. [es]

Associative memory

The type of memory that allows us to associate one thing with another. For example, we can recall a complete sensory experience, including sounds and scenes, when we hear only a few bars of music. We can also recognise a familiar face even in an unfamiliar environment. An associative ANN recalls the closest ‘stored’ training pattern when presented with a similar input pattern. The **Hopfield network** is an example of the associative ANN. [nn]

Attribute

A property of an **object**. For example, the object ‘computer’ might have such attributes as ‘model’, ‘processor’, ‘memory’ and ‘cost’. [es]

Axon

A single long branch of a biological **neuron** that carries the output signal (**action potential**) from the cell. An axon may be as long as a metre. In an ANN, an axon is modelled by the neuron’s output. [nn]

Backward chaining

An **inference technique** that starts with a hypothetical solution (a goal) and works backward, matching **rules** from the **rule base** with **facts** from the **database** until the **goal** is either verified or proven wrong. Also referred to as **Goal-driven reasoning**. [es]

Back-propagation

see **Back-propagation algorithm**. [nn]

Back-propagation algorithm

The most popular method of **supervised learning**. The algorithm has two phases. First, a training input pattern is presented to the **input layer**. The network propagates the input pattern from layer to layer until the output pattern is generated by the **output layer**. If this pattern is different from the desired output, an **error** is calculated and then propagated backwards through the network from the output layer to the input layer. The **weights** are modified as the error is propagated. Also referred to as **Back-propagation**. [nn]

Bayesian reasoning

A statistical approach to uncertainty management in **expert systems** that propagates uncertainties throughout the system based on a **Bayesian rule** of evidence. [es]

Bayesian rule

A statistical method for updating the probabilities attached to certain **facts** in the light of new evidence. [es]

Bidirectional associative memory (BAM)

A class of **neural networks** that emulates characteristics of **associative memory**; proposed by Bart Kosko in the 1980s. The BAM associates patterns from one set to patterns from another set, and vice versa. Its basic architecture consists of two fully connected **layers** – an **input layer** and an **output layer**. [nn]

Bit

A binary digit. The smallest unit of information. **Data** stored in a computer is composed of bits. [ke]

Bit map

A representation of an image by rows and columns of dots. Bit maps can be stored, displayed and printed by a computer. Optical scanners are used to transform text or pictures on paper into bit maps. The scanner processes the image by dividing it into hundreds of **pixels** per inch and representing each pixel by either 1 or 0. [ke]

Black-box

A model that is opaque to its user; although the model can produce correct results, its internal relationships are not known. An example of a black-box is a **neural network**. To understand the relationships between outputs and inputs of a black-box, **sensitivity analysis** can be used. [ke]

Boolean logic

A system of logic based on Boolean algebra, named after George Boole. It deals with two truth values: 'true' and 'false'. The Boolean conditions of true and false are often represented by 0 for 'false' and 1 for 'true'.

Branch

A connection between **nodes** in a **decision tree**. [dm]

Building block

A group of **genes** that gives a **chromosome** a high **fitness**. According to the building block hypothesis, an optimal solution can be found by joining several building blocks together in a single chromosome. [ec]

Byte

A set of eight **bits** that represents the smallest addressable item of information in a modern computer. The information in a byte is equivalent to a letter in a word. One gigabyte is about 1,000,000,000 (2^{30} or 1,073,741,824) bytes, approximately equal to 1000 novels. [ke]

C

A general-purpose programming language, originally developed at Bell Labs along with the UNIX operating system.

C++

An object-oriented extension of C.

CART (Classification and Regression Trees)

A tool for **data mining** that uses **decision trees**. CART provides a set of **rules** that can be applied to a new data set for predicting outcomes. CART segments **data records** by creating binary splits. [dm]

Categorical data

The **data** that fits into a small number of discrete categories. For example, gender (male or female) or marital status (single, divorced, married or widowed). [ke]

Centroid technique

A **defuzzification** method that finds the point, called the *centroid* or *centre of gravity*, where a vertical line would slice the **aggregate set** into two equal masses. [fl]

Certainty factor

A number assigned to a **fact** or a **rule** to indicate the certainty or confidence one has that this fact or rule is valid. Also referred to as **Confidence factor**. [es]

Certainty theory

A theory for managing uncertainties in **expert systems** based on inexact **reasoning**. It uses **certainty factors** to represent the level of belief in a hypothesis given that a particular event has been observed. [es]

Child

see **Offspring**. [ec]

Child

In a **decision tree**, a child is a **node** produced by splitting the **data** of a node located at the preceding hierarchical level of the tree. A child node holds a subset of the data contained in its **parent**. [dm]

Chromosome

A string of **genes** that represent an individual. [ec]

Class

A group of **objects** with common **attributes**. *Animal*, *person*, *car* and *computer* are all classes. [es]

Class-frame

A frame that represents a **class**. [es]

Clipping

A common method of correlating the **consequent** of a **fuzzy rule** with the truth value of the rule **antecedent**. The method is based on cutting the consequent **membership function** at the level of the antecedent truth. Since the top of the membership function is sliced, the clipped **fuzzy set** loses some information. [fl]

Cloning

Creating an **offspring** that is an exact copy of a **parent**. [ec]

Clustering

The process of dividing a heterogeneous group of objects into homogeneous subgroups. Clustering **algorithms** find groups of items that are similar in some respect. For example, clustering can be used by an insurance company to group customers according to age, assets, income and prior claims. [ke]

Coding

The process of transforming information from one scheme of representation to another. [ec]

Cognitive science

The interdisciplinary study of how **knowledge** is acquired and used. Its contributing disciplines include **artificial intelligence**, psychology, linguistics, philosophy, neuroscience, and education. Also, the study of **intelligence** and intelligent systems, with reference to intelligent behaviour as computation.

Common-sense

A general **knowledge** of how to solve real-world problems, usually obtained through practical experience. [ke]

Competitive learning

Unsupervised learning in which **neurons** compete among themselves such that only one neuron will respond to a particular input pattern. The neuron that wins the 'competition' is called the winner-takes-all neuron. **Kohonen self-organising feature maps** are an example of an ANN with competitive learning. [nn]

Complement

In classical **set theory**, the complement of set *A* is the set of elements that are not members of *A*. In the **fuzzy set theory**, the complement of a set is an opposite of this set. [fl]

Confidence factor

see **Certainty factor**. [es]

Conflict

A state in which two or more **production rules** match the **data** in the **database**, but only one rule can actually be fired in a given cycle. [es]

Conflict resolution

A method for choosing which **production rule** to fire when more than one rule can be fired in a given cycle. [es]

Conjunction

The logical operator AND that joins together two **antecedents** in a **production rule**. [es]

Connection

A link from one **neuron** to another to transfer signals. Also referred to as **synapse**, which is often associated with the **weight** that determines the strength of the transferred signal. [nn]

Consequent

A conclusion or action in the IF part of a **rule**. [es]

Continuous data

The **data** that takes an infinite number of possible values on some interval. Examples of continuous data include height, weight, household income, the living area of a house. Continuous variables are usually measurements, and do not have to be integers. [ke]

Convergence

An ANN is said to have converged when the **error** has reached a preset threshold indicating that the network has learned the task. [nn]

Convergence

A tendency of individuals in the population to be the same. A **genetic algorithm** is said to have converged when a solution has been reached. [ec]

Crossover

A **reproduction** operator that creates a new **chromosome** by exchanging parts of two existing chromosomes. [ec]

Crossover probability

A number between zero and one that indicates the probability of two chromosomes crossing over. [ec]

Darwinism

Charles Darwin's theory that states that **evolution** occurs through natural **selection**, coupled with random changes of inheritable characteristics. [ec]

Data

Facts, measurements, or observations. Also, a symbolic representation of facts, measurements, or observations. Data is what we collect and store.

Database

A collection of structured **data**. Database is the basic component of an **expert system**. [es]

Data-driven reasoning

see **Forward chaining**. [es]

Data cleaning

The process of detecting and correcting obvious errors and replacing missing **data** in a **database**. Also referred to as **Data cleansing**. [dm]

Data cleansing

see **Data cleaning**. [dm]

Data mining

The extraction of **knowledge** from **data**. Also, the exploration and analysis of large

amounts of data in order to discover meaningful patterns and **rules**. The ultimate goal of data mining is to discover knowledge. [dm]

Data record

A set of values corresponding to the **attributes** of a single **object**. A data record is a row in a **database**. Also referred to as **Record**. [dm]

Data visualisation

The graphical representation of **data** that helps the **user** in understanding the structure and meaning of the information contained in the data. Also referred to as **Visualisation**. [dm]

Data warehouse

A large **database** that includes millions, even billions, of **data records** designed to support decision-making in organisations. It is structured for rapid on-line queries and managerial summaries. [dm]

Decision tree

A graphical representation of a data set that describes the **data** by tree-like structures. A decision tree consists of **nodes**, **branches** and **leaves**. The tree always starts from the **root node** and grows down by splitting the data at each level into new nodes. Decision trees are particularly good at solving classification problems. Their main advantage is **data visualisation**. [dm]

Decision-support system

An interactive computer-based system designed to help a person or a group of people to make decisions in a specific **domain**. [es]

Deductive reasoning

Reasoning from the general to the specific. [es]

Defuzzification

The last step in **fuzzy inference**; the process of converting a combined output of **fuzzy rules** into a crisp (numerical) value. The input for the defuzzification process is the **aggregate set** and the output is a single number. [fl]

Degree of membership

A numerical value between 0 and 1 that represents the degree to which an element belongs to a particular **set**. Also referred to as **Membership value**. [fl]

Delta rule

A procedure for updating **weights** in a **perceptron** during **training**. The delta rule determines the weight correction by multiplying the neuron's input with the **error** and the **learning rate**. [nn]

Demon

A **procedure** that is attached to a **slot** and executed if the slot value is changed or needed. A demon usually has an IF-THEN structure. Demon and **method** are often used as synonyms. [es]

DENDRAL

A rule-based expert system developed at Stanford University in the late 1960s for analysing chemicals, based on the mass spectral **data** provided by a mass spectrometer. DENDRAL

marked a major 'paradigm shift' in AI: a shift from general-purpose, knowledge-sparse methods to domain-specific, knowledge-intensive techniques. [es]

Dendrite

A branch of a biological **neuron** that transfers information from one part of a cell to another. Dendrites typically serve an input function for the cell, although many dendrites also have output functions. In an ANN, dendrites are modelled by inputs to a neuron. [nn]

Deterministic model

A mathematical model that postulates exact relationships between **objects** (no random variables are recognised). Given a set of input **data**, the deterministic model determines its output with complete certainty. [es]

Discrete data

The **data** that takes only a finite number of distinct values. Discrete data are usually (but not necessarily) counts. Examples of discrete data include the number of children in a family, the number of bedrooms in a house, the number of masts of a sailing vessel. [ke]

Disjunction

The logical operator OR that joins together two **antecedents** in a **production rule**. [es]

Domain

A relatively narrow problem area. For example, diagnosing blood diseases within the medical diagnostics field. **Expert systems** work in well-focused specialised domains. [es]

Domain expert

see **Expert**. [es]

EMYCIN

Empty MYCIN, an **expert system shell** developed at Stanford University in the late 1970s. It has all features of the MYCIN system except the **knowledge** of infectious blood diseases. EMYCIN is used to develop diagnostic **expert systems**. [es]

End-user

see **User**. [es]

Epoch

The presentation of the entire **training set** to an ANN during **training**. [nn]

Error

The difference between the actual and desired outputs in an ANN with **supervised learning**. [nn]

Euclidean distance

The shortest distance between two points in space. In Cartesian coordinates, the Euclidean distance between two points, (x_1, y_1) and (x_2, y_2) , is determined by the Pythagorean theorem $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$.

Evolution

A series of genetic changes by which a living organism acquires characteristics that distinguish it from other organisms. [ec]

Evolution strategy

A numerical optimisation procedure similar to a focused Monte Carlo search. Unlike **genetic algorithms**, evolution strategies use only a **mutation** operator, and do not require a problem to be represented in a coded form. Evolution strategies are used for solving technical optimisation problems when no analytical objective function is available, and no conventional optimisation method exists. [ec]

Evolutionary computation

Computational models used for simulating **evolution** on a computer. The field of evolutionary computation includes **genetic algorithms**, **evolution strategies** and **genetic programming**. [ec]

Exhaustive search

A problem-solving technique in which every possible solution is examined until an acceptable one is found. [es]

Expert

A person who has deep **knowledge** in the form of **facts** and **rules** and strong practical experience in a particular **domain**. Also referred to as **Domain expert**. [es]

Expert system

A computer program capable of performing at the level of a human **expert** in a narrow **domain**. Expert systems have five basic components: the **knowledge base**, the **database**, the **inference engine**, the **explanation facilities** and the **user interface**. [es]

Expert system shell

A skeleton **expert system** with the **knowledge** removed. Also referred to as **Shell**. [es]

Explanation facility

A basic component of an **expert system** that enables the **user** to query the expert system about how it reached a particular conclusion and why it needs a specific **fact** to do so. [es]

Facet

A means of providing extended **knowledge** about an **attribute** of a **frame**. Facets are used to establish the attribute value, control the **user** queries, and tell the **inference engine** how to process the attribute. [es]

Fact

A statement that has the property of being either true or false. [es]

Feedback neural network

A **topology** of an ANN in which **neurons** have feedback loops from their outputs to their inputs. An example of a feedback network is the **Hopfield network**. Also referred to as **Recurrent network**. [nn]

Feedforward neural network

A **topology** of an ANN in which **neurons** in one **layer** are connected to the neurons in the next layer. The input signals are propagated in a forward direction on a layer-by-layer basis. An example of a feedforward network is a multilayer **perceptron**. [nn]

Field

A space allocated in a **database** for a particular **attribute**. (In a spreadsheet, fields are called

cells.) A tax form, for example, contains a number of fields: your name and address, tax file number, taxable income, etc. Every field in a database has a name, called the field name. [dm]

Firing a rule

The process of executing a **production rule**, or more precisely, executing the THEN part of a rule when its IF part is true. [es]

Fitness

The ability of a living organism to survive and reproduce in a specific environment. Also, a value associated with a **chromosome** that assigns a relative merit to that chromosome. [ec]

Fitness function

A mathematical function used for calculating the **fitness** of a **chromosome**. [ec]

Forward chaining

An **inference technique** that starts from the known **data** and works forward, matching the **facts** from the **database** with **production rules** from the **rule base** until no further rules can be fired. Also referred to as **Data-driven reasoning**. [es]

Frame

A **data** structure with typical **knowledge** about a particular **object**. Frames are used to represent knowledge in a **frame-based expert system**. [es]

Frame-based expert system

An **expert system** in which **frames** represent a major source of **knowledge**, and both **methods** and **demons** are used to add actions to the frames. In frame-based systems, **production rules** play an auxiliary role. [es]

Fuzzification

The first step in **fuzzy inference**; the process of mapping crisp (numerical) inputs into degrees to which these inputs belong to the respective **fuzzy sets**. [fl]

Fuzzy expert system

An **expert system** that uses **fuzzy logic** instead of **Boolean logic**. A fuzzy expert system is a collection of **fuzzy rules** and **membership functions** that are used to reason about **data**. Unlike conventional expert systems, which use **symbolic reasoning**, fuzzy expert systems are oriented towards numerical processing. [fl]

Fuzzy inference

The process of reasoning based on **fuzzy logic**. Fuzzy inference includes four steps: **fuzzification** of the input variables, **rule evaluation**, **aggregation** of the rule outputs and **defuzzification**. [fl]

Fuzzy logic

A system of logic developed for representing conditions that cannot be easily described by the binary terms 'true' and 'false'. The concept was introduced by Lotfi Zadeh in 1965. Unlike **Boolean logic**, fuzzy logic is multi-valued and handles the concept of partial truth (truth values between 'completely true' and 'completely false'). Also referred to as **Fuzzy set theory**. [fl]

Fuzzy rule

A conditional statement in the form: IF x is A THEN y is B , where x and y are **linguistic variables**, and A and B are **linguistic values** determined by **fuzzy sets**. [fl]

Fuzzy set

A set with fuzzy boundaries, such as 'short', 'average' or 'tall' for men's height. To represent a fuzzy set in a computer, we express it as a function and then map the elements of the set to their **degree of membership**. [fl]

Fuzzy set theory

see **Fuzzy logic**. [fl]

Fuzzy singleton

A fuzzy set with a **membership function** equal to unity at a single point on the **universe of discourse** and zero everywhere else. Also referred to as **Singleton**. [fl]

Fuzzy variable

A quantity that can take on **linguistic values**. For example, the fuzzy variable 'temperature', might have values such as 'hot', 'medium' and 'cold'. [fl]

Gene

A basic unit of a **chromosome** that controls the development of a particular feature of a living organism. In Holland's chromosome, a gene is represented by either 0 or 1. [ec]

General Problem Solver (GPS)

An early AI system that attempted to simulate human methods of problem solving. The GPS was the first attempt to separate the problem-solving technique from the **data**. However, the program was based on the general-purpose **search** mechanism. This approach, now referred to as a weak method, applied weak information about the problem domain, and resulted in weak performance of the program in solving real-world problems. [es]

Generation

One iteration of a **genetic algorithm**. [ec]

Generalisation

The ability of an ANN to produce correct results from **data** on which it has not been trained. [nn]

Genetic algorithm

A type of **evolutionary computation** inspired by Darwin's theory of **evolution**. A genetic algorithm generates a population of possible solutions encoded as **chromosomes**, evaluates their **fitness**, and creates a new population by applying genetic operators – **crossover** and **mutation**. By repeating this process over many **generations**, the genetic algorithm breeds an optimal solution to the problem. [ec]

Genetic programming

An application of **genetic algorithms** to computer programs. Genetic programming is most easily implemented where the programming language permits a program to be manipulated as data and the newly created data to be executed as a program. This is one of the reasons why **LISP** is used as the main language for genetic programming. [ec]

Genetic operator

An operator in **genetic algorithms** or **genetic programming**, which acts upon the **chromosome** in order to produce a new individual. Genetic operators include **crossover** and **mutation**. [ec]

Global minimum

The lowest value of a function over the entire range of its input parameters. During **training**, the **weights** of an ANN are adjusted to find the global minimum of the **error** function. [nn]

Global optimisation

Finding the true optimum in the entire **search space**. [ec]

Goal

A hypothesis that an **expert system** attempts to prove. [es]

Goal-driven reasoning

see **Backward chaining**. [es]

Hard limit activation function

An **activation function** represented by the **step** and **sign functions**. Also referred to as **Hard limiter**. [nn]

Hard limiter

see **Hard limit activation function**. [nn]

Hebb's Law

The **learning** law introduced by Donald Hebb in the late 1940s; it states that if **neuron i** is near enough to excite neuron j and repeatedly participates in its activation, the **synaptic connection** between these two neurons is strengthened and neuron j becomes more sensitive to stimuli from neuron i . This law provides the basis for **unsupervised learning**. [nn]

Hebbian learning

Unsupervised learning that relates a change in the **weight** of the **synaptic connection** between a pair of **neurons** to a product of the incoming and outgoing signals. [nn]

Hedge

A qualifier of a **fuzzy set** used to modify its shape. Hedges include adverbs such as 'very', 'somewhat', 'quite', 'more or less' and 'slightly'. They perform mathematical operations of concentration by reducing the **degree of membership** of fuzzy elements (e.g. very tall men), dilation by increasing the degree of membership (e.g. more or less tall men) and intensification by increasing the degree of membership above 0.5 and decreasing those below 0.5 (e.g. indeed tall men). [fl]

Heuristic

A strategy that can be applied to complex problems; it usually – but not always – yields a correct solution. Heuristics, which are developed from years of experience, are often used to reduce complex problem solving to more simple operations based on judgment. Heuristics are often expressed as **rules of thumb**. [es]

Heuristic search

A search technique that applies **heuristics** to guide the **reasoning**, and thus reduce the **search space** for a solution. [es]

Hidden layer

A **layer of neurons** between the **input** and **output layers**; called 'hidden' because neurons in this layer cannot be observed through the input/output behaviour of the **neural network**. There is no obvious way to know what the desired output of the hidden layer should be. [nn]

Hidden neuron

A **neuron** in the **hidden layer**. [nn]

Hopfield network

A single-layer **feedback neural network**. In the Hopfield network, the output of each **neuron** is fed back to the inputs of all other neurons (there is no self-feedback). The Hopfield network usually uses **McCulloch and Pitts neurons** with the **sign activation function**. The Hopfield network attempts to emulate characteristics of the **associative memory**. [nn]

Hybrid system

A system that combines at least two intelligent technologies. For example, combining a **neural network** with a fuzzy system results in a hybrid neuro-fuzzy system. [ke]

Hypothesis

A statement that is subject to proof. Also, a **goal** in **expert systems** that use **backward chaining**. [es]

Individual

A single member of a **population**. [ec]

Inductive reasoning

Reasoning from the specific to the general. [es]

Inference chain

The sequence of steps that indicates how an **expert system** applies **rules** from the **rule base** to reach a conclusion. [es]

Inference engine

A basic component of an **expert system** that carries out **reasoning** whereby the expert system reaches a solution. It matches the **rules** provided in the **rule base** with the **facts** contained in the **database**. Also referred to as **Interpreter**. [es]

Inference technique

The technique used by the **inference engine** to direct **search** and **reasoning** in an **expert system**. There are two principal techniques: **forward chaining** and **backward chaining**. [es]

Inheritance

The process by which all characteristics of a **class-frame** are assumed by the **instance-frame**. Inheritance is an essential feature of **frame-based systems**. A common use of inheritance is to impose default features on all instance-frames. [es]

Initialisation

The first step of the **training** algorithm that sets **weights** and **thresholds** to their initial values. [nn]

Input layer

The first **layer** of **neurons** in an ANN. The input layer accepts input signals from the outside world and redistributes them to neurons in the next layer. The input layer rarely includes computing neurons and does not process input patterns. [nn]

Input neuron

A **neuron** in the **input layer**. [nn]

Instance

A specific **object** from a **class**. For example, class 'computer' may have instances *IBM Aptiva S35* and *IBM Aptiva S9C*. In **frame-based expert systems**, all characteristics of a class are inherited by its instances. [es]

Instance

A member of the **schema**. For example, **chromosomes** $\boxed{1110}$ and $\boxed{1010}$ are the instances of the schema $\boxed{1* * 0}$. [ec]

Instance-frame

A **frame** that represents an **instance**. [es]

Instantiation

The process of assigning a specific value to a variable. For example, 'August' is an instantiation of the object 'month'. [es]

Intelligence

The ability to learn and understand, to solve problems and to make decisions. A machine is thought intelligent if it can achieve human-level performance in some cognitive task.

Interpreter

see **Inference engine**. [es]

Intersection

In classical **set theory**, an intersection between two **sets** contains elements shared by these sets. For example, the intersection of *tall men* and *fat men* contains all men who are tall *and* fat. In **fuzzy set theory**, an element may partly belong to both sets, and the intersection is the lowest **membership value** of the element in both sets. [fl]

is-a

An **arc** (also known as 'a-kind-of') that associates a superclass with its subclasses in a **frame-based expert system**. For example, if *car is-a vehicle*, then *car* represents a subclass of more general superclass *vehicle*. Each subclass inherits all features of the superclass. [es]

Knowledge

A theoretical or practical understanding of a subject. Knowledge is what helps us to make informed decisions.

Knowledge acquisition

The process of acquiring, studying and organising **knowledge**, so that it can be used in a **knowledge-based system**. [ke]

Knowledge base

A basic component of an **expert system** that contains knowledge about a specific **domain**. [es]

Knowledge-based system

A system that uses stored **knowledge** for solving problems in a specific **domain**. A knowledge-based system is usually evaluated by comparing its performance with the performance of a human **expert**. [es]

Knowledge engineer

A person who designs, builds and tests a **knowledge-based system**. The knowledge engineer captures the **knowledge** from the **domain expert**, establishes reasoning methods and chooses the development software. [ke]

Knowledge engineering

The process of building a **knowledge-based system**. There are six main steps: assess the problem; acquire data and knowledge; develop a prototype system; develop a complete system; evaluate and revise the system; integrate and maintain the system. [ke]

Knowledge representation

The process of structuring **knowledge** to be stored in a **knowledge-based system**. In AI, **production rules** are the most common type of knowledge representation. [ke]

Kohonen self-organising feature maps

A special class of ANNs with **competitive learning** introduced by Teuvo Kohonen in the late 1980s. The Kohonen map consists of a single **layer** of computation **neurons** with two types of **connections**: forward connections from the neurons in the input layer to the neurons in the output layer, and lateral connections between neurons in the output layer. The lateral connections are used to create a competition between neurons. A neuron learns by shifting its **weights** from inactive connections to active ones. Only the winning neuron and its neighbourhood are allowed to learn. [nn]

Layer

A group of **neurons** that have a specific function and are processed as a whole. For example, a **multilayer perceptron** has at least three layers: an **input layer**, an **output layer** and one or more **hidden layers**. [nn]

Leaf

A bottom-most **node** of a **decision tree**; a node without **children**. Also referred to as a **Terminal node**. [dm]

Learning

The process by which **weights** in an ANN are adjusted to achieve some desired behaviour of the network. Also referred to as **Training**. [nn]

Learning rate

A positive number less than unity that controls the amount of changes to the **weights** in the ANN from one iteration to the next. The learning rate directly affects the speed of network **training**. [nn]

Learning rule

A procedure for modifying **weights** during **training** in an ANN. [nn]

Linear activation function

An **activation function** that produces an output equal to the net input of a **neuron**. Neurons with the linear activation function are often used for linear approximation. [nn]

Linguistic variable

A variable that can have values that are language elements, such as words and phrases. In **fuzzy logic**, terms linguistic variable and **fuzzy variable** are synonyms. [fl]

Linguistic value

A language element that can be assumed by a **fuzzy variable**. For example, the fuzzy variable 'income' might assume such linguistic values as 'very low', 'low', 'medium', 'high' and 'very high'. Linguistic values are defined by **membership functions**. [fl]

LISP (LIST Processor)

One of the oldest high-level programming languages. LISP, which was developed by John McCarthy in the late 1950s, has become a standard language for **artificial intelligence**.

Local minimum

The minimum value of a function over a limited range of its input parameters. If a local minimum is encountered during **training**, the desired behaviour of an ANN may never be achieved. The usual method of getting out of a local minimum is to randomise the **weights** and continue training. [nn]

Machine learning

An adaptive mechanism that enable computers to learn from experience, learn by example and learn by analogy. Learning capabilities improve the performance of an intelligent system over time. Machine learning is the basis of adaptive systems. The most popular approaches to machine learning are **artificial neural networks** and **genetic algorithms**.

Massaging data

The process of modifying the **data** before it is applied to the **input layer** of an ANN. [nn]

McCulloch and Pitts neuron model

A **neuron** model proposed by Warren McCulloch and Walter Pitts in 1943, which is still the basis for most **artificial neural networks**. The model consists of a linear combiner followed by a **hard limiter**. The net input is applied to the hard limiter, which produces an output equal to +1 if its input is positive and -1 if it is negative. [nn]

Membership function

A mathematical function that defines a **fuzzy set** on the **universe of discourse**. Typical membership functions used in **fuzzy expert systems** are triangles and trapezoids. [fl]

Membership value

see Degree of membership. [fl]

Metaknowledge

Knowledge about knowledge; knowledge about the use and control of **domain** knowledge in **expert systems**. [es]

Metarule

A **rule** that represents **metaknowledge**. A metarule determines a strategy for the use of task-specific rules in the **expert system**. [es]

Method

A **procedure** associated with an **attribute** of a **frame**. A method can determine the attribute's value or execute a series of actions when the attribute's value changes. Most **frame-based expert systems** use two types of methods: **WHEN CHANGED** and **WHEN NEEDED**. Method and **demon** are often used as synonyms. [es]

Momentum constant

A positive constant less than unity included in the **delta rule**. The use of momentum accelerates **learning** in a **multilayer perceptron** and helps to prevent it from getting caught in a **local minimum**. [nn]

Multilayer perceptron

The most common **topology** of an ANN in which **perceptrons** are connected together to form **layers**. A multilayer perceptron has the **input layer**, at least one **hidden layer** and the **output layer**. The most popular method of training a multilayer perceptron is **back-propagation**. [nn]

Multiple inheritance

The ability of an **object** or a **frame** to inherit information from multiple superclasses. [es]

Mutation

A **genetic operator** that randomly changes the **gene** value in a **chromosome**. [ec]

Mutation probability

A number between zero and one that indicates the probability of **mutation** occurring in a single **gene**. [ec]

MYCIN

A classic **rule-based expert system** developed in the 1970s for the diagnosis of infectious blood diseases. The system used **certainty factors** for managing uncertainties associated with **knowledge** in medical diagnosis. [es]

Natural selection

The process by which the most fit individuals have a better chance to mate and reproduce, and thereby to pass their genetic material on to the next generation. [ec]

Neural computing

A computational approach to modelling the human brain that relies on connecting a large number of simple processors to produce complex behaviour. Neural computing can be implemented on specialised hardware or with software, called **artificial neural networks**, that simulates the structure and functions of the human brain on a conventional computer. [nn]

Neural network

A system of processing elements, called **neurons**, connected together to form a network. The fundamental and essential characteristic of a biological neural network is the ability to learn. **Artificial neural networks** also have this ability; they are not programmed, but learn from examples through repeated adjustments of their **weights**. [nn]

Neuron

A cell that is capable of processing information. A typical neuron has many inputs (**dendrites**) and one output (**axon**). The human brain contains roughly 10^{12} neurons.

Also, a basic processing element of an ANN that computes the weighted sum of the input signals and passes the result through its **activation function** to generate an output. [nn]

Node

A decision point of a **decision tree**. [dm]

Noise

A random external disturbance that affects a transmitted signal. Noisy **data** contain errors associated with the way the data was collected, measured and interpreted. [dm]

NOT

A logical operator used for representing the negation of a statement. [es]

Object

A concept, abstraction or thing that can be individually selected and manipulated, and that has some meaning for the problem at hand. All objects have identity and are clearly distinguishable. *Michael Black, Audi 5000 Turbo, IBM Aptiva S35* are examples of objects. In **object-oriented programming**, an object is a self-contained entity that consists of both **data** and **procedures** to manipulate the data. [es]

Object-oriented programming

A programming method that uses **objects** as a basis for analysis, design and implementation. [es]

Offspring

An individual that was produced through **reproduction**. Also referred to as a **child**. [ec]

Operational database

A **database** used for the daily operation of an organisation. **Data** in operational databases is regularly updated. [dm]

OPS

A high-level programming language derived from **LISP** for developing **rule-based expert systems**. [es]

Optimisation

An iterative process of improving the solution to a problem with respect to a specified objective function. [ec]

OR

A logical operator; when used in a **production rule**, it implies that if any of the **antecedents** joined with OR is true, then the rule **consequent** must also be true. [es]

Overfitting

A state in which an ANN has memorised all the training examples, but cannot generalise. Overfitting may occur if the number of **hidden neurons** is too big. The practical approach to preventing overfitting is to choose the smallest number of hidden neurons that yields good **generalisation**. Also referred to as **Over-training**. [nn]

Over-training

see **Overfitting**. [nn]

Output layer

The last **layer** of **neurons** in an ANN. The output layer produces the output pattern of the entire network. [nn]

Output neuron

A **neuron** in the **output layer**. [nn]

Parallel processing

A computational technique that carries out multiple tasks simultaneously. The human brain is an example of a parallel information-processing system: it stores and processes information simultaneously throughout the whole biological **neural network**, rather than at specific locations. [nn]

Parent

An individual that produces one or more other individuals, known as **offspring** or **child**. [ec]

Parent

In a **decision tree**, a parent node is a **node** that splits its data between nodes at the next hierarchical level of the tree. The parent node contains a complete data set, while **child** nodes hold subsets of that set. [dm]

Pattern recognition

Identification of visual or audio patterns by computers. Pattern recognition involves converting patterns into digital signals and comparing them with patterns already stored in the memory. **Artificial neural networks** are successfully applied to pattern recognition, particularly in such areas as voice and character recognition, radar target identification and robotics. [nn]

Perceptron

The simplest form of a **neural network**, suggested by Frank Rosenblatt. The operation of the perceptron is based on the **McCulloch and Pitts neuron model**. It consists of a single **neuron** with adjustable **synaptic weights** and a **hard limiter**. The perceptron learns a task by making small adjustments in the weights to reduce the difference between the actual and desired outputs. The initial weights are randomly assigned and then updated to obtain an output consistent with the training examples. [nn]

Performance

A statistical evaluation of **fitness**. [ec]

Performance graph

A graph that shows the average **performance** of the entire **population** and the performance of the best individual in the population over the chosen number of **generations**. [ec]

Pixel

Picture Element; a single point in a graphical image. Computer monitors display pictures by dividing the screen into thousands (or millions) of pixels arranged into rows and columns. The pixels are so close together that they appear as one image. [ke]

Population

A group of individuals that breed together. [ec]

Premise

see **Antecedent**. [es]

Probability

A quantitative description of the likely occurrence of a particular event. Probability is expressed mathematically as a number with a range between zero (an absolute impossibility) to unity (an absolute certainty). [es]

Procedure

A self-contained arbitrary piece of computer code. [es]

Production

A term often used by cognitive psychologists to describe a **rule**. [es]

Production rule

A statement expressed in the IF (antecedent) THEN (consequent) form. If the **antecedent** is true, then the **consequent** is also true. Also referred to as **Rule**. [es]

PROLOG

A high-level programming language developed at the University of Marseilles in the 1970s as a practical tool for programming in logic; a popular language for **artificial intelligence**.

PROSPECTOR

An **expert system** for mineral exploration developed by the Stanford Research Institute in the late 1970s. To represent **knowledge**, PROSPECTOR used a combined structure that incorporated **production rules** and a **semantic network**. [es]

Query tool

Software that allows a **user** to create and direct specific questions to a **database**. A query tool provides the means for extracting the desired information from a database. [dm]

Reasoning

The process of drawing conclusions or inferences from observations, **facts** or assumptions. [es]

Record

see **Data record**. [dm]

Recurrent network

see **Feedback network**. [nn]

Reproduction

The process of creating **offspring** from **parents**. [ec]

Root

see **Root node**. [dm]

Root node

The top-most **node** of a **decision tree**. The tree always starts from the root node and grows down by splitting the **data** at each level into new nodes. The root node contains the entire data set (all **data records**), and **child** nodes hold subsets of that set. Also referred to as **Root**. [dm]

Roulette wheel selection

A method of selecting a particular individual in the **population** to be a **parent** with a probability equal to its **fitness** divided by the total fitness of the population. [ec]

Rule

see **Production rule**. [es]

Rule base

The **knowledge base** that contains a set of **production rules**. [es]

Rule-based expert system

An expert system whose **knowledge base** contains a set of **production rules**. [es]

Rule evaluation

The second step in **fuzzy inference**; the process of applying the fuzzy inputs to the **antecedents** of **fuzzy rules**, and determining the **truth value** for the antecedent of each rule. If a given rule has multiple antecedents, the fuzzy operation of **intersection** or **union** is carried out to obtain a single number that represents the result of evaluating the antecedent. [fl]

Rule of thumb

A **rule** that expresses a **heuristic**. [es]

Scaling

A method of correlating the **consequent** of a **fuzzy rule** with the **truth value** of the rule **antecedent**. It is based on adjusting the original **membership function** of the rule consequent by multiplying it by the truth value of the rule antecedent. Scaling helps to preserve the original shape of the **fuzzy set**. [fl]

Search

The process of examining a set of possible solutions to a problem in order to find an acceptable solution. [es]

Search space

The set of all possible solutions to a given problem. [es]

Self-organised learning

see **Unsupervised learning**. [nn]

Semantic network

A method of **knowledge representation** by a graph made up of labelled nodes and **arcs**, where the nodes represent **objects** and the arcs describe relationships between these objects. [es]

Set

A collection of elements (also called members).

Set theory

The study of **sets** or **classes** of **objects**. The set is the basic unit in mathematics. Classical set theory does not acknowledge the **fuzzy set**, whose elements can belong to a number of sets to some degree. Classical set theory is bivalent: the element either does or does not belong to a particular set. That is, classical set theory gives each member of the set the value of 1, and all members that are not within the set a value of 0.

Schema

A bit string of ones, zeros and asterisks, where each asterisk can assume either value 1 or 0. For example, the schema $\overline{1 * * 0}$ stands for a set of four 4-bit strings with each string beginning with 1 and ending with 0. [ec]

Schema theorem

A theorem that relates the expected number of **instances** of a given **schema** in the consequent **generation** with the **fitness** of this schema and the average fitness of **chromosomes** in the current generation. The theorem states that a schema with above-average fitness tends to occur more frequently in the next generation. [ec]

Selection

The process of choosing **parents** for **reproduction** based on their **fitness**. [ec]

Sensitivity analysis

A technique of determining how sensitive the output of a model is to a particular input. Sensitivity analysis is used for understanding relationships in opaque models, and can be applied to **neural networks**. Sensitivity analysis is performed by measuring the network output when each input is set (one at a time) to its minimum and then its maximum values. [ke]

Shell

see Expert system shell. [es]

Sigmoid activation function

An **activation function** that transforms the input, which can have any value between plus and minus infinity, into a reasonable value in the range between 0 and 1. **Neurons** with this function are used in a **multilayer perceptron**. [nn]

Sign activation function

A **hard limit activation function** that produces an output equal to +1 if its input is positive and -1 if it is negative. [nn]

Singleton

see Fuzzy singleton. [fl]

Slot

A component of a **frame** in a **frame-based system** that describes a particular **attribute** of the frame. For example, the frame 'computer' might have a slot for the attribute 'model'. [es]

Soma

The body of a biological **neuron**. [nn]

Step activation function

A **hard limit activation function** that produces an output equal to +1 if its input is positive and 0 if it is negative. [nn]

Supervised learning

A type of **learning** that requires an external teacher, who presents a sequence of training examples to the ANN. Each example contains the input pattern and the desired output pattern to be generated by the network. The network determines its actual output and compares it with the desired output from the training example. If the output from

the network differs from the desired output specified in the training example, the network **weights** are modified. The most popular method of supervised learning is **back-propagation**. [nn]

Survival of the fittest

The law according to which only individuals with the highest **fitness** can survive to pass on their genes to the next generation. [ec]

Symbol

A character or a string of characters that represents some **object**. [es]

Symbolic reasoning

Reasoning with **symbols**. [es]

Synapse

A chemically mediated **connection** between two **neurons** in a biological **neural network**, so that the state of the one cell affects the state of the other. Synapses typically occur between an **axon** and a **dendrite**, though there are many other arrangements. See also **Connection**. [nn]

Synaptic weight

see **Weight**. [nn]

Terminal node

see **Leaf**. [dm]

Test set

A data set used for testing the ability of an ANN to generalise. The test data set is strictly independent of the **training set**, and contains examples that the network has not previously seen. Once **training** is complete, the network is validated with the test set. [nn]

Threshold

A specific value that must be exceeded before the output of a **neuron** is generated. For example, in the **McCulloch and Pitts neuron model**, if the net input is less than the threshold, the neuron output is -1 . But if the net input is greater than or equal to the threshold, the neuron becomes activated and its output attains a value $+1$. Also referred to as **Threshold value**. [nn]

Threshold value

see **Threshold**. [nn]

Topology

A structure of a **neural network** that refers to the number of **layers** in the neural network, the number of **neurons** in each layer, and **connections** between neurons. Also referred to as **Architecture**. [nn]

Toy problem

An artificial problem, such as a game. Also, an unrealistic adaptation of a complex problem. [es]

Training

see **Learning**. [nn]

Training set

A data set used for **training** an ANN. [nn]

Transfer function

see **Activation function**. [nn]

Truth value

In general, the terms **truth value** and **membership value** are used as synonyms. The truth value reflects the truth of a fuzzy statement. For example, the fuzzy proposition x is A (0.7) suggests that element x is a member of **fuzzy set** A to the degree 0.7. This number represents the truth of the proposition. [fl]

Turing test

A test designed to determine whether a machine can pass a behaviour test for **intelligence**. Turing defined the intelligent behaviour of a computer as the ability to achieve human-level performance in cognitive tasks. During the test a human interrogates *someone* or *something* by questioning it via a neutral medium such as a remote terminal. The computer passes the test if the interrogator cannot distinguish the machine from a human.

Union

In classical **set theory**, the union of two **sets** consists of every element that falls into either set. For example, the union of *tall men* and *fat men* contains all men who are either tall *or* fat. In **fuzzy set theory**, the union is the reverse of the **intersection**, that is, the union is the largest **membership value** of the element in either set. [fl]

Universe of discourse

The range of all possible values that are applicable to a given variable. [fl]

Unsupervised learning

A type of **learning** that does not require an external teacher. During **learning** an ANN receives a number of different input patterns, discovers significant features in these patterns and learns how to classify input data into appropriate categories. Also referred to as **Self-organised learning**. [nn]

User

A person who uses a **knowledge-based system** when it is developed. For example, the user might be an analytical chemist determining the molecular structures, a junior doctor diagnosing an infectious blood disease, an exploration geologist trying to discover a new mineral deposit, or a power system operator seeking an advice in an emergency. Also referred to as **End-user**. [es]

User interface

A means of communication between a **user** and a machine. [es]

Visualisation

see **Data visualisation**. [dm]

Weight

The value associated with a **connection** between two **neurons** in an ANN. This value

determines the strength of the connection and indicates how much of the output of one neuron is fed to the input of another. Also referred to as **Synaptic weight**. [nn]

WHEN CHANGED method

A **procedure** attached to a **slot** of a **frame** in a **frame-based expert system**. The WHEN CHANGED method is executed when new information is placed in the slot. [es]

WHEN NEEDED method

A **procedure** attached to a **slot** of a **frame** in a **frame-based expert system**. The WHEN NEEDED method is executed when information is needed for the problem solving, but the slot value is unspecified. [es]

