SOFT COMPUTING
MODULE 1

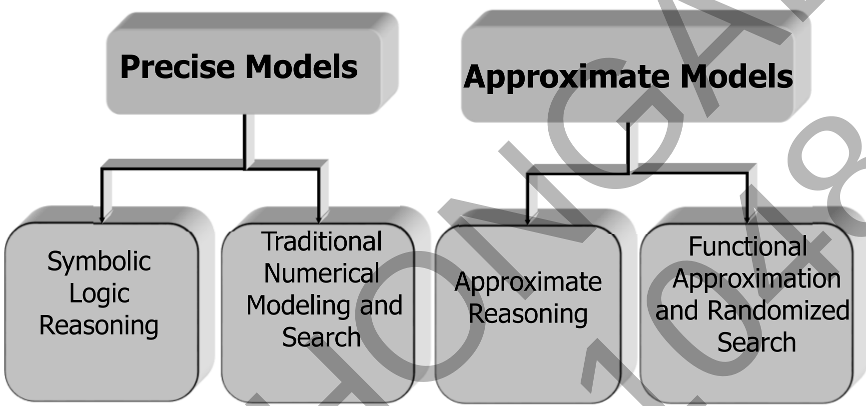
Dr. R.B.Ghongade,
VIIT, Pune-411048

SOFT COMPUTING CONSTITUENTS AND CONVENTIONAL ARTIFICIAL INTELLIGENCE

- Soft Computing (SC): The symbiotic use of many emerging problem-solving disciplines.
- *Soft computing is an emerging approach to computing which parallels the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision.* (Lotfi A. Zadeh, 1992)
- Soft computing consists of several computing paradigms,
  - neural networks
  - fuzzy set theory, approximate reasoning
  - derivative-free optimization methods such as genetic algorithms and simulated annealing

PROBLEM SOLVING TECHNIQUES

HARD COMPUTING **SOFT COMPUTING**

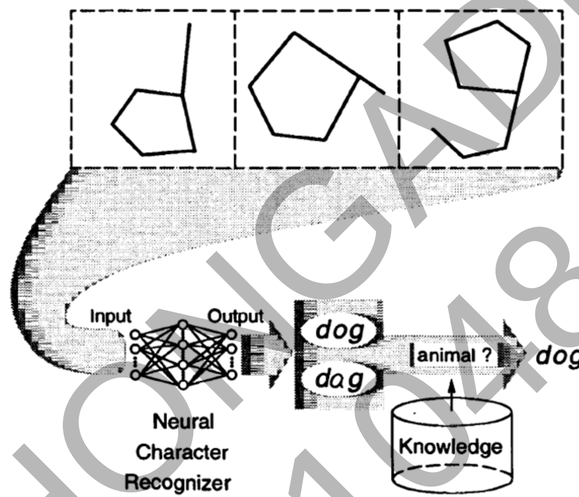


Methodology	Strength
Neural network	Learning and adaptation
Fuzzy set theory	Knowledge representation via fuzzy if-then rules
Genetic algorithm and simulated annealing	Systematic random search
Conventional AI	Symbolic manipulation

- The seamless integration of these methodologies forms the core of soft computing
- The synergism allows soft computing to incorporate human knowledge effectively, deal with imprecision and uncertainty, and learn to adapt to unknown or changing environment for better performance

An Example

- Neural character recognizer and a knowledge base are used together to determine the meaning of a hand-written word
- The neural character recognizer generates two possible answers "dog" and "dag," since the middle character could be
- either an "o" or "a”
- If the knowledge base provides an extra piece of information that the given word is related to animals, then the answer "dog" is picked up correctly

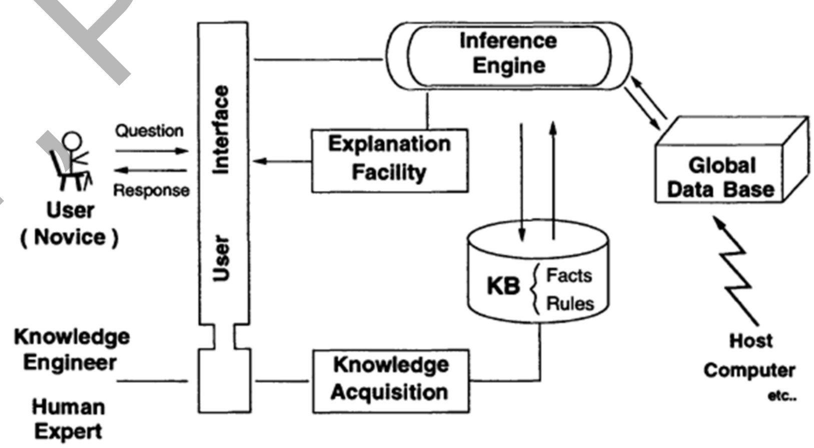


	Conventional AI	Neural networks	Fuzzy systems	Other methodologies
1940s	1947 Cybernetics	1943 McCulloch-Pitts neuron model		
1950s	1956 Artificial Intelligence	1957 Perceptron		
1960s	1960 Lisp language	1960s Adaline Madaline	1965 Fuzzy sets	
1970s	mid- 1970s Knowledge Engineering (expert systems)	1974 Birth of Back-propagation algorithm 1975 Cognitron Neocognitron	1974 Fuzzy controller	1970s Genetic algorithm
1980s		1980 Self-organizing map 1982 Hopfield Net 1983 Boltzmann machine 1986 Backpropagation algorithm boom	1985 Fuzzy modeling (TSK model)	mid- 1980s Artificial life Immune modeling
1990s			1990s Neuro-fuzzy modeling 1991 ANFIS 1994 CANFIS	1990 Genetic programming

From Conventional AI to Computational Intelligence

- Humans usually employ *natural languages* in reasoning and drawing conclusions
- Conventional AI attempts to mimic human intelligent behavior by expressing it in language forms or symbolic rules
- AI manipulates symbols on the assumption that such behavior can be stored in symbolically structured knowledge bases-called *physical symbol system hypothesis*
- Symbolic systems provide a good basis for modeling human experts in some narrow problem areas if explicit knowledge is available –Eg. an expert system

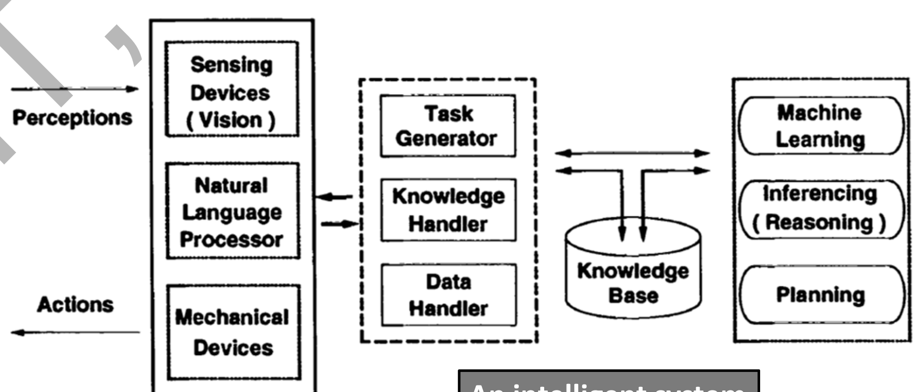
A typical expert system



Short comings of symbolicism

- In practice, the symbolic manipulations limit the situations to which the conventional AI theories can be applied as knowledge acquisition and representation are difficult tasks
- Hence more attention has been directed toward biologically inspired methodologies such as brain modeling, evolutionary algorithms, and immune modeling; they simulate biological mechanisms responsible for generating natural intelligence
- These methodologies are somewhat *orthogonal* to conventional AI approaches and generally compensate for the shortcomings of symbolicism

- The long-term goal of AI research is the creation and understanding of *machine intelligence*
- Soft computing shares the same ultimate goal with AI



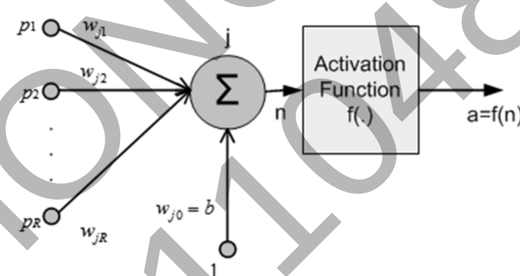
An intelligent system

NEURAL NETWORKS

DARPA Neural Network Study (1988, AFCEA International Press, p. 60):

... a neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes.

An artificial neuron



DEFINITIONS OF NEURAL NETWORKS

According to Haykin (1994), p. 2:

A neural network is a massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. It resembles the brain in two respects:

- Knowledge is acquired by the network through a learning process.
- Interneuron connection strengths known as synaptic weights are used to store the knowledge

According to Nigrin (1993), p. 11:

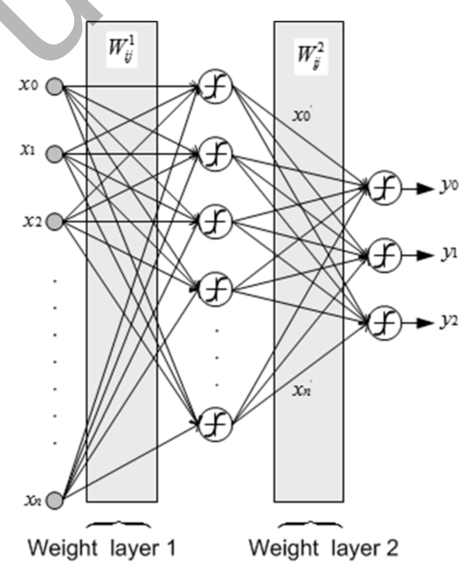
A neural network is a circuit composed of a very large number of simple processing elements that are neurally based. Each element operates only on local information.

Furthermore each element operates asynchronously; thus there is no overall system clock.

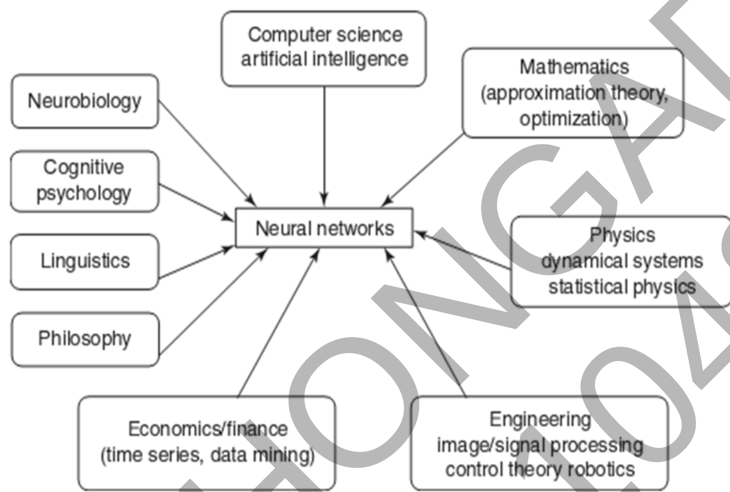
According to Zurada (1992):

Artificial neural systems, or neural networks, are physical cellular systems which can acquire, store and utilize experiential knowledge.

A multi-layered neural network



MULTIDISCIPLINARY VIEW OF NEURAL NETWORKS



FUZZY LOGIC

- Origins: Multivalued Logic for treatment of imprecision and vagueness
  - 1930s: Post, Kleene, and Lukasiewicz attempted to represent undetermined, unknown, and other possible intermediate truth-values.
  - 1937: Max Black suggested the use of a consistency profile to represent vague (ambiguous) concepts.
  - 1965: Zadeh proposed a complete theory of fuzzy sets (and its isomorphic fuzzy logic), to represent and manipulate ill-defined concepts.

FUZZY LOGIC – LINGUISTIC VARIABLES

- Fuzzy logic gives us a language (with syntax and local semantics) in which we can translate our qualitative domain knowledge.
- Linguistic variables to model dynamic systems
- These variables take linguistic values that are characterized by:
  - a label - a sentence generated from the syntax
  - a meaning - a membership function determined by a local semantic procedure

FUZZY LOGIC – REASONING METHODS

- The meaning of a linguistic variable may be interpreted as an elastic constraint on its value.
- These constraints are propagated by fuzzy inference operations, based on the generalized modus-ponens.
- An FL Controller (FLC) applies this reasoning system to a Knowledge Base (KB) containing the problem domain heuristics.
- The inference is the result of interpolating among the outputs of all relevant rules.
- The outcome is a membership distribution on the output space, which is defuzzified to produce a crisp output.

GENETIC ALGORITHM

EVOLUTIONARY PROCESS

DEFINITION OF GENETIC ALGORITHM

– The genetic algorithm is a probabilistic search algorithm that iteratively transforms a set (called a population) of mathematical objects (typically fixed-length binary character strings), each with an associated fitness value, into a new population of offspring objects using the Darwinian principle of natural selection and using operations that are patterned after naturally occurring genetic operations, such as crossover (sexual recombination) and mutation.

STEPS INVOLVED IN GENETIC ALGORITHM

The genetic algorithms follow the evolution process in the nature to find the better solutions of some complicated problems. Foundations of genetic algorithms are given in Holland (1975) and Goldberg (1989) books.
Genetic algorithms consist the following steps:

- Initialization
- Selection
- Reproduction with crossover and mutation

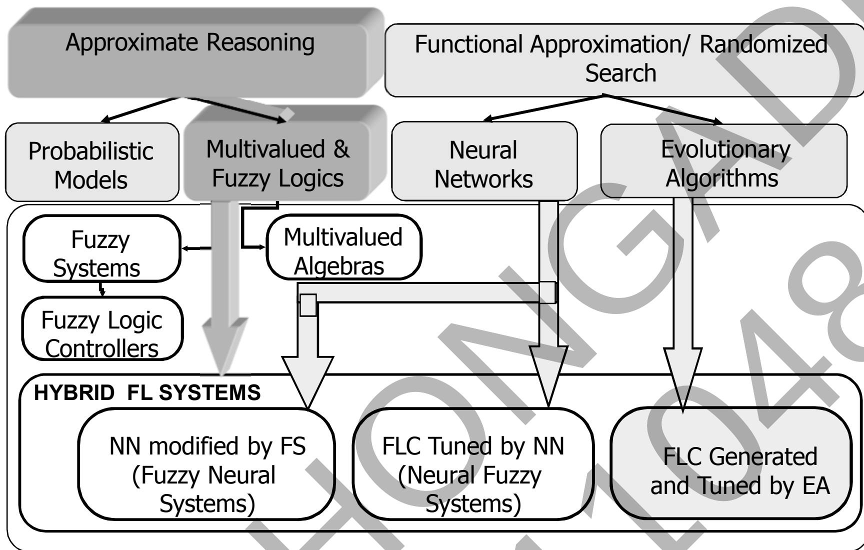
Selection and reproduction are repeated for each generation until a solution is reached.
During this procedure a certain strings of symbols, known as chromosomes, evaluate toward better solution.

HYBRID SYSTEMS

Hybrid systems enables one to combine various soft computing paradigms and result in a best solution. The major three hybrid systems are as follows:

- Hybrid Fuzzy Logic (FL) Systems
- Hybrid Neural Network (NN) Systems
- Hybrid Evolutionary Algorithm (EA) Systems

SOFT COMPUTING: HYBRID FL SYSTEMS



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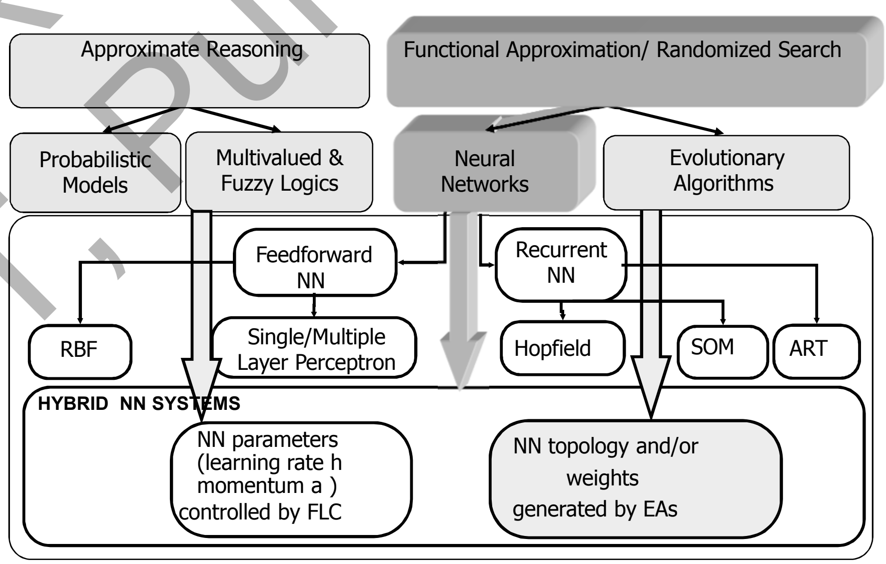
SOFT COMPUTING: HYBRID NN SYSTEMS



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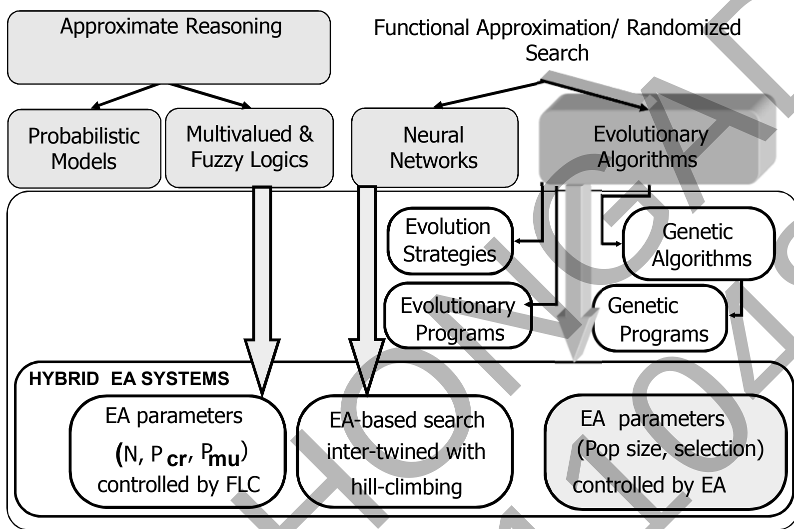
SOFT COMPUTING: HYBRID EA SYSTEMS



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NEURO-FUZZY AND SOFT COMPUTING CHARACTERISTICS

- Human expertise
  - SC utilizes human expertise in the form of fuzzy if-then rules, as well as in conventional knowledge representations, to solve practical problems
- Biologically inspired computing models
  - Inspired by biological neural networks, artificial neural networks are employed extensively in soft computing to deal with perception, pattern recognition, and nonlinear regression and classification problems
- New optimization techniques
  - Soft computing applies innovative optimization methods arising from various sources; they are genetic algorithms (inspired by the evolution and selection process), simulated annealing (motivated by thermodynamics), the random search method, these optimization methods do not require the gradient vector of an objective function, so they are more flexible in dealing with complex optimization problems

NEURO-FUZZY AND SOFT COMPUTING CHARACTERISTICS

- Numerical computation
  - Unlike symbolic AI, soft computing relies mainly on numerical computation. Incorporation of symbolic techniques in soft computing is an active research area within this field.
- New application domains
  - Because of its numerical computation, soft computing has found a number of new application domains besides that of AI approaches. These application domains are mostly computation intensive and include adaptive signal processing, adaptive control, nonlinear system identification, nonlinear regression, and pattern recognition.
- Model-free learning
  - Neural networks and adaptive fuzzy inference systems have the ability to construct models using only target system sample data. Detailed insight into the target system helps set up the initial model structure, but it is not mandatory.

NEURO-FUZZY AND SOFT COMPUTING CHARACTERISTICS

- Intensive computation
  - Without assuming too much background knowledge of the problem being solved, neuro-fuzzy and soft computing rely heavily on high-speed number-crunching computation to find rules or regularity in data sets. This is a common feature of all areas of computational intelligence
- Fault tolerance
  - Both neural networks and fuzzy inference systems exhibit fault tolerance. The deletion of a neuron in a neural network, or a rule in a fuzzy inference system, does not necessarily destroy the system. Instead, the system continues performing because of its parallel and redundant architecture, although performance quality gradually deteriorates

NEURO-FUZZY AND SOFT COMPUTING CHARACTERISTICS

- Goal driven characteristics
  - Neuro-fuzzy and soft computing are goal driven; the path leading from the current state to the solution does not really matter as long as we are moving toward the goal in the long run. This is particularly true when used with derivative-free optimization schemes, such as genetic algorithms, simulated annealing, and the random search method. Domain specific knowledge helps reduces the amount of computation and search time, but it is not a requirement.
- Real-world applications
  - Most real-world problems are large scale and inevitably incorporate built-in uncertainties; this precludes using conventional approaches that require detailed description of the problem being solved. Soft computing is an integrated approach that can usually utilize specific techniques within subtasks to construct generally satisfactory solutions to real-world problems

APPLICATIONS OF SOFT COMPUTING

- Handwriting Recognition
- Image Processing and Data Compression
- Automotive Systems and Manufacturing
- Soft Computing to Architecture
- Decision-support Systems
- Soft Computing to Power Systems
- Neuro Fuzzy systems
- Fuzzy Logic Control
- Machine Learning Applications
- Speech and Vision Recognition Systems
- Process Control and So on