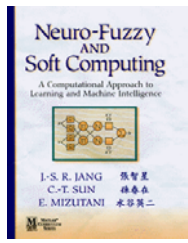
Chapter 1: Introduction to Neuro-Fuzzy (NF) and Soft Computing (SC)

- Introduction (1.1)
- SC Constituants and Conventional Artificial Intelligence (AI) (1.2)
- NF and SC Characteristics (1.3)



Jyh-Shing Roger Jang et al., *Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence*, First Edition, Prentice Hall, 1997

Introduction (1.1)

– Main Goal

- SC is an innovative approach to constructing computationally intelligent systems
- Intelligent systems that possess humanlike expertise within a specific domain, adapt themselves and learn to perform better in changing environments
- These systems explain how they make decisions or take actions
- They are composed of two features: “adaptivity” & “knowledge”

- Neural Networks (NN) that recognize patterns & adapts themselves to cope with changing environments
- Fuzzy inference systems that incorporate human knowledge & perform inferencing & decision making

Adaptivity + Expertise = NF & SC

SC Constituants and Conventional AI (1.2)

"SC is an emerging approach to computing which parallel the remarkable ability of the human mind to reason and learn in a environment of uncertainty and imprecision" [Lotfi A. Zadeh, 1992]

- SC consists of several computing paradigms including:
  - NN
  - Fuzzy set theory
  - Approximate reasoning
  - Derivative-free optimization methods such as genetic algorithms (GA) & simulated annealing (SA)

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

Table 1.1: SC constituents (the first three items) and conventional AI

- These methodologies form the core of SC
- In general, SC does not perform much symbolic manipulation
- SC in this sense complements conventional AI approaches

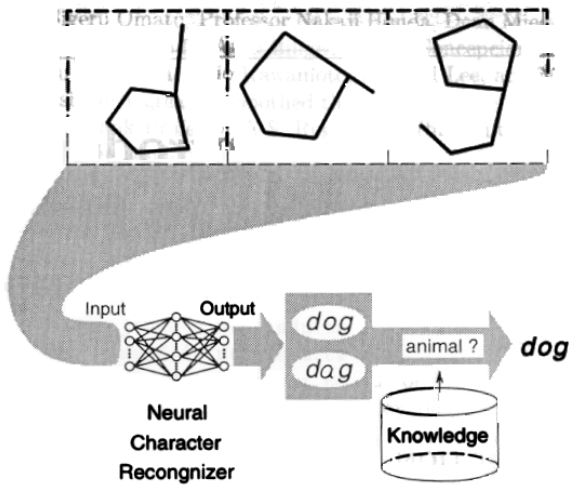


Fig 1.1.: A Neural character recognizer and a knowledge base cooperate in responding to 3 handwritten characters that form a word "dog".

– From conventional AI to computational intelligence

- Conventional AI manipulates symbols on the assumption that human intelligence behavior can be stored in symbolically structured knowledge bases: this is known as: " The physical symbol system hypothesis"

- The knowledge-based system (or expert system) is an example of the most successful conventional AI product

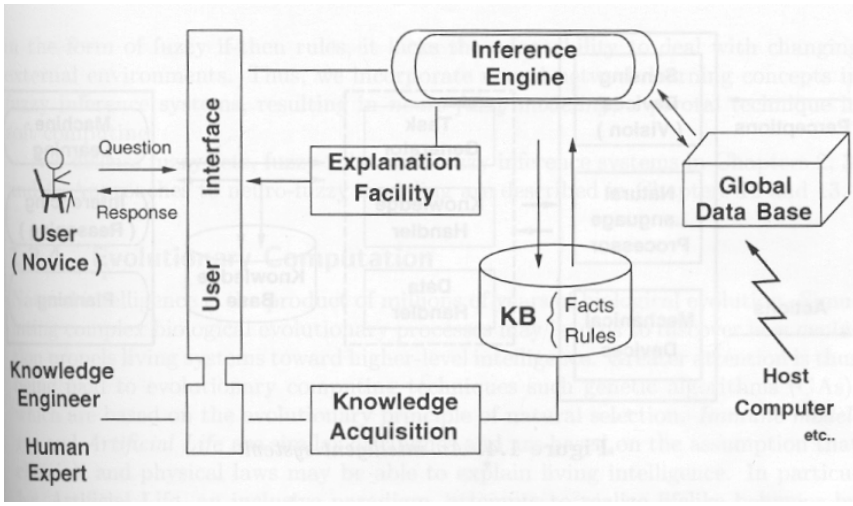


Fig 1.3: An expert system: one of the most successful (conventional AI products)

– Several definitions have been given to conventional AI

- "AI is the study of agents that exists in an environment and perceive and act" [S. Russel & P. Norvig]
- "AI is the act of making computers do smart things" [Waldrop]
- "AI is a programming style, where programs operate on data according to rules in order to accomplish goals" [W.A. Taylor]

- "AI is the activity of providing such machines as computers with the ability to display behavior that would be regarded as intelligent if it were observed in humans" [R. Mc Leod]
- "Expert system is a computer program using expert knowledge to attain high levels of performance in a narrow problem area" [D.A. Waterman]
- "Expert system is a caricature of the human expert, in the sense that it knows almost everything about almost nothing" [A.R. Mirzai]

– AI is changing rapidly, these definitions are already obsolete!

– Knowledge acquisition and representation has limited the application of AI theories (shortcoming of symbolicism)

– SC has become a part of "modern AI"

– Researchers have directed their attention toward biologically inspired methodologies such as brain modeling, evolutionary algorithm and immune modeling

- These new paradigms simulate chemico-biological mechanisms responsible for natural intelligence generation
- SC and AI share the same long-term goal: build and understand machine intelligence
- An intelligent system can for example sense its environment (perceive) and act on its perception (react)
- SC is evolving under AI influences that sprang from cybernetics (the study of information and control in human and machines)

- Neural Network (NN)
  - Imitation of the natural intelligence of the brain
  - Parallel processing with incomplete information
  - Nerve cells function about 10^6 times slower than electronic circuit gates, but human brains process visual and auditory information much faster than modern computers
  - The brain is modeled as a continuous-time non linear dynamic system in connectionist architectures
  - Connectionism replaced symbolically structured representations
  - Distributed representation in the form of weights between a massive set of interconnected neurons

– Fuzzy set theory

- Human brains interpret imprecise and incomplete sensory information provided by perceptive organs
- Fuzzy set theory provides a systematic calculus to deal with such information linguistically
- It performs numerical computation by using linguistic labels stimulated by membership functions
- It lacks the adaptability to deal with changing external environments ==> incorporate NN learning concepts in fuzzy inference systems: NF modeling

– Evolutionary computation

- Natural intelligence is the product of millions of years of biological evolution
- Simulation of complex biological evolutionary processes
- GA is one computing technique that uses an evolution based on natural selection
- Immune modeling and artificial life are similar disciplines based on chemical and physical laws
- GA and SA population-based systematic random search (RA) techniques

- NF and SC characteristics (1.3)
  - With NF modeling as a backbone, SC can be characterized as:
    - Human expertise (fuzzy if-then rules)
    - Biologically inspired computing models (NN)
    - New optimization techniques (GA, SA, RA)
    - Numerical computation (no symbolic AI so far, only numerical)