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)

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 Constituents 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)
These methodologies form the core of SC

In general, SC does not perform much symbolic manipulation

SC in this sense complements conventional AI approaches

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

“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 symbolism)

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)