Session : Introduction to AI and CI

Course Title: Computational Intelligence
Course Code: 19CSE422A

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Objectives of this Session

I wish to:

1. Introduce the terms intelligence, artificial intelligence (AI), computational intelligence (CI) and soft computing

2. Discuss the pitfalls of traditional AI

3. Give formal definitions of CI

4. Outline dominant paradigms of CI: Artificial immune systems (AISs), Artificial neural networks (ANNs), Evolutionary computing (EC), Fuzzy logic (FL) and Swarm intelligence (SI)

5. Discuss the synergism in CI tools

Intended Outcomes of this Session

At the end of this session, the student will be able to:

1. Discuss intelligence, Artificial Intelligence (AI) and Computational Intelligence (CI)

2. Distinguish between AI, CI and soft computing

3. List the building blocks of CI

4. Relate the biology with the dominant paradigms of CI

5. Highlight the limitations of the traditional AI

6. Summarize the synergism in CI paradigms

Recommended Resources for this Session

1. Konar, A. (2005). *Computational Intelligence: Principles, Techniques and Applications*. Syracuse, NJ, USA, Springer-Verlag New York, Inc.

2. Engelbrecht, A. P. (2007). *Computational intelligence: An introduction*. Chichester, England, John Wiley & Sons.

3. Eberhart, R. C. (2007). *Computational Intelligence: Concepts to Implementations*. San Francisco, CA, USA, Morgan Kaufmann Publishers Inc.

Intelligence

- The ability to learn or understand or to deal with new or trying situations

- The ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria

- The ability to comprehend, to understand and profit from experience, having the capacity for thought and reason to a high degree

- The capability of a system to adapt its behavior to meet its goals in a range of environments. It is a property of all purpose-driven decision-makers

- Other keywords: Creativity, Skill, Consciousness, Emotion and Intuition

Artificial Intelligence

- AI aims at emulating human intelligence so as to enable them to act and think like human beings

- AI is a vast discipline of knowledge that includes logic, deductive reasoning, expert systems, case-based reasoning, machine learning, planning, intelligent search and perception building

- AI is a combination of several research disciplines, such as computer science, physiology, philosophy, sociology and biology

- Conventional AI mostly involves methods now classified as machine learning, characterized by formalism and statistical analysis

- This is also known as symbolic AI, logical AI, neat AI and Good-Old-Fashioned AI

Pitfalls of the Traditional AI

- Problem solving methods in traditional AI deal with representation of the problem states by symbols and construction of a set of IF-THEN rules to describe the transitions in the problem space

- The states of the problem are then matched with the IF part of the rules, and on successful matching the selected rule is fired causing a transition to a new state as obtained from the THEN part of the rule

- To keep the rules firable until the goal is found, the knowledge rule is enriched with a large number of rules

- This results in more search time, and degraded efficiency of the reasoning system

- A few IF-THEN rules, and allowing partial matching with IF part mitigates this limitation. **Fuzzy logic (FL)** enables this.

Pitfalls of the Traditional AI

- AI is good in inductive and analogy-based reasoning; but, inefficient in supervised learning. **ANNs** are remarkably successful in this task

- AI is not competent to handle real-world optimization problems. **genetic algorithms (GAs) and SI algorithms** perform much better in this area

- Decision making is based on facts and the level of their precision. The quality of decision may degrade when input facts are imprecise. If inputs come from multiple sources, their level of precision can be improved using data fusion

- Traditional AI is not concerned with data fusion

Emergence of Computational Intelligence

- Traditional AI was incompetent to meet the increasing demands of search, optimization and machine learning in information systems and industrial automation

- Shortcomings became more visible with successive failures of the Japanese project *Fifth Generation Computer Systems*

- The failure of classical AI opened up new avenues for non-conventional models of intelligence in real-world applications

- Enormous successes have been achieved through the modeling of biological intelligence, resulting in so-called "intelligent systems"

- These gave rise to a new discipline called **CI**

- ANNs, fuzzy systems, evolutionary computing and artificial life are the major building blocks of CI

Formal Definitions of CI

- CI can be defined as *the computational models and tools of intelligence capable of inputting raw numerical sensory data, processing them by exploiting representational parallelism, and pipelining of the problem, generating reliable and timely responses and withstanding high fault tolerance*

- CI is *the study of adaptive mechanisms to enable or facilitate intelligent behavior in complex and changing environments*

- These mechanisms include paradigms that exhibit an ability to learn or adapt to new situations, to generalize, abstract, discover and associate

- ANNs, fuzzy systems, EC, SI and AISs are the dominating paradigms of CI.

Requirements of CI

A system is computationally intelligent when it deals with only numerical (low-level) data, has pattern recognition components, does not use knowledge in the AI sense; and additionally, when it exhibits:

1. Computational adaptability,
2. Computational fault tolerance,
3. Speed approaching human-like turnaround, and
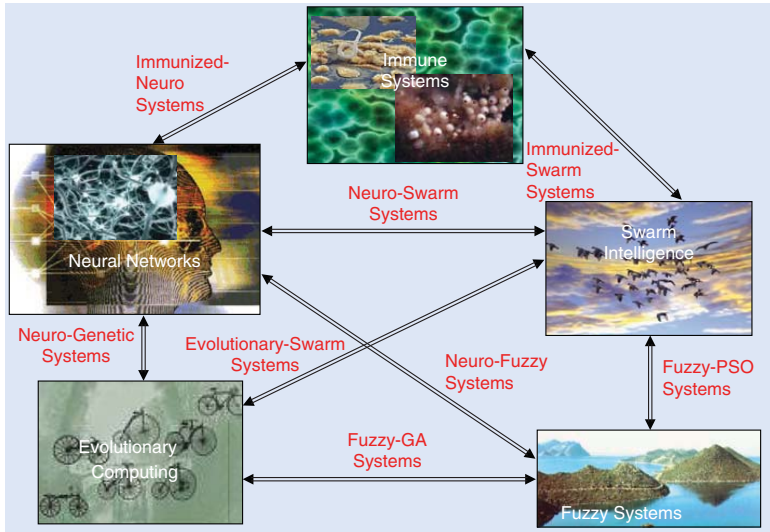4. Error rates that approximate human performance

Relation Between AI and CI

Computational Intelligence
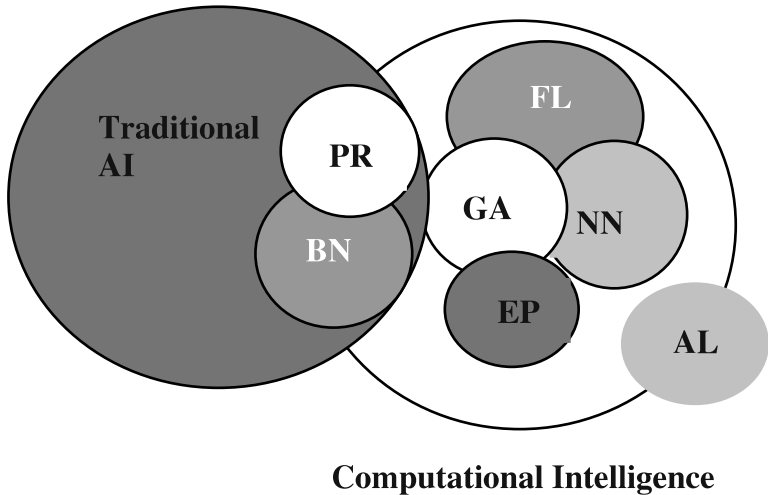
(Courtesy: Dr. Amit Konar)

Paradigms of CI

(Courtesy: Dr. Ganesh Kumar Venayagamoorthy)

Soft Computing and Hard computing

- Hard computing is best for solving the mathematical problems which dont solve the problems of the real world.
- Soft computing is better used in solving real-world problems as it is a randomly defined process that can be analyzed statistically but not with precision.
- Hard computing relies on binary logic and predefined instructions like a numerical analysis and brisk software and uses two-valued logic. Soft computing is based on the model of the human mind where it has probabilistic reasoning, fuzzy logic, and uses multivalued logic.
- Hard computing needs exact input of the data and is sequential; on the other hand, Soft computing can handle an abundance of data and handles multiple computations which might not be exact in a parallel way.

Soft Computing and Hard computing

- Hard computing takes a lot of time to complete tasks and is costly while soft computing tolerance of uncertainty and imprecision is estimated to achieve Machine Intelligence Quotient (MIQ) and lower cost. It also provides better communication.

- Hard computing is best suited for solving mathematical problems which give some precise answers. Soft computing resolves the nonlinear issues that involve uncertainty and impreciseness as it has human-like intelligence that can resolve the real-life issue.

- Hard computing takes a lot of time in computing as it requires the stated analytical model and the model soft computing is based on is that of human intelligence.

Soft Computing and Hard computing

- In the current scenario, soft computing and hard computing are being used together in various industries. The aim is to develop a system that analyzes with high stability.
- Computing is particularly important for solving real-time applications. Soft computing provides usable solutions to complex problems, and it is also referred to as CI.
- CI holds the tolerance of half-truth and approximation that the traditional computing method does not have.
- Some popular examples of CI are: Handwritten Script Recognition, Image Processing and Data Compression, Automotive Systems and Manufacturing, Soft computing based Architecture, Decision Support System, Power System Analysis, Bioinformatics, Investment and Trading, Handwritten Script Recognition etc.

Soft Computing

- Synergism of CI tools became a hot research area

- Inspired by the success of hybrid CI tools, Zadeh rechristened the discipline as **Soft Computing**

- *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 and imprecision*

- Guiding principles of soft computing: exploit the tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness and low solution cost.

- Soft computing is a consortium of methodologies, which either singly or in combination, serve to provide effective tools

Evolutionary Computing
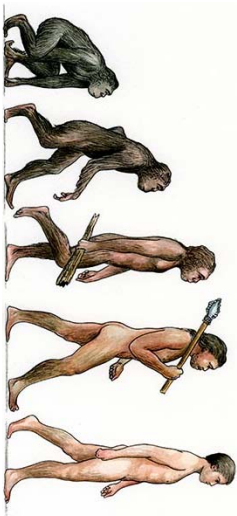
- EC models natural evolution, where the main concept is the survival of the fittest

- In natural evolution, survival is achieved through reproduction. Offspring, reproduced from two parents, contain genetic material of both parents, hopefully the best characteristics of each parent

- Those individuals that inherit the bad characteristics are weak and lose the battle to survive

- In some bird species, a hatchling manages to get more food, gets stronger and kicks out all its siblings from the nest to die

Applications of EC
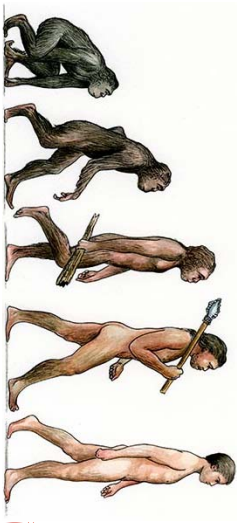
- **Optimization:** Gas pipeline transmission, multiple-fault diagnosis, robot track determination, schedule optimization, load distribution by an electric utility

- **Classification:** Evolution of neural networks, rule-based machine learning systems for pipeline operations and classifier systems for high-level semantic networks

Fuzzy Logic
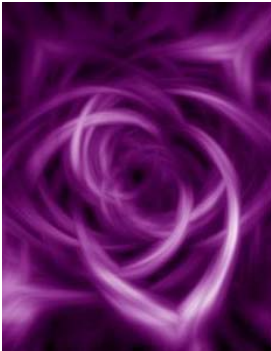
- Set theory requires elements to be either part of a set or not. Binary-valued logic requires the values of parameters to be either 0 or 1, with similar constraints on the outcome of an inferencing process

- Fuzzy sets and FL allow what is referred to as approximate reasoning

- With fuzzy sets, an element belongs to a set to a certain degree of certainty

- FL allows reasoning with these uncertain facts to infer new facts, with a degree of certainty associated with each fact

- In a sense, FL allows the modeling of commonsense

Applications of FL

- **Control Systems**: subway systems, cement kilns, traffic signal systems, home appliances, video cameras, and various subsystems of automobiles including the transmission and brake systems

- A familiar application is the circuitry inside a video camera that stabilizes the image in spite of the unsteady holding of the camera

- **Expert systems:** medical diagnostics, foreign exchange trading, robot navigation, scheduling, automobile diagnostics, and the selection of business strategies
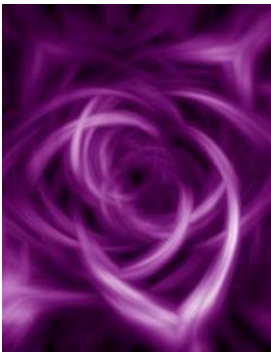
Artificial Neural Networks
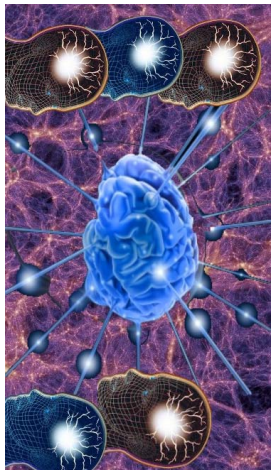
- ANN, usually called a neural network (NN), is a mathematical or computational model inspired by the structure and functional aspects of biological neural networks

- ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning

- ANNs can be used to infer a function from observations

- Broad application categories: function approximation, pattern classification, data processing, and time-series prediction

Applications of ANNs

- **Classification:** If an EEG data represents an epileptiform spike waveform, diagnoses of tumors
- **Content Addressable Memory:** Obtaining the complete version of a pattern by providing a partial version
- **Clustering or Compression:** Reduction of the dimensionality of an input in speech recognition
- Generation of Sequences or Patterns: Composition of music, financial engineering
- **Control Systems:** A neural network-based control system can deal with all of the nonlinearities of a system
- Can be used to model the nonlinear system in the process of designing the control system
- The development time for a neural network control system is shorter than it is for traditional techniques

Artificial Immune Systems

- AISs are biologically inspired models for immunization of engineering systems
- The pioneering task of AIS is to detect and eliminate non-self materials, called antigens, such as bacteria or cancer cells
- The AIS also plays a great role to maintain its own system against dynamically changing environment
- The immune systems thus aim at providing a new methodology suitable for dynamic problems dealing with unknown or hostile environments
- Areas of applications: Classification, clustering, data mining and anomaly detection

Swarm Intelligence

- SI originated from the study of colonies (of ants, bees and termites, etc.) or swarms of social organisms flock of birds, school of fish

- Studies of the social behavior of organisms (individuals) in swarms prompted the design of very efficient optimization and clustering algorithms

- SI is an innovative distributed intelligent paradigm optimization problems

- Applications include combinatorial optimization, function approximation, clustering, optimization of mechanical structures, and solving systems of equations

Synergism in CI

- Each tool of CI has its own pros and cons. Each fits to particular class(es) of applications. A cooperative synthesis of these tools may give better computational model that can complement the limitation of a tool with the judicious use of another

- Many such hybrid tools are popular in a vast range of applications

- The synergism may be classified into strongly coupled and loosely coupled synergism

- In strongly coupled synergism, the individual tools are mixed in an inseparable manner

- In loosely coupled synergism, the individual tools have their structural identity

Synergism in CI

- **Neuro-Fuzzy synergism:** Facilitates machine learning from approximate data or approximate reasoning using the knowledge obtained from machine learning

- **Neuro-GA synergism:** GA can be used for training neural networks. GA-based training can outperform the typical backproagation training

- **Fuzzy-GA Synergism:** Typically, GAs are used to optimize the parameters of fuzzy systems

- **Neuro-Fuzzy-GA Synergism:** ANN can be used as a classifier with fuzzy membership functions pre-tuned through a GA. Alternately, GA may be used to train a fuzzy neural network

Conclusion

1. AI has a impressive vision of artificial systems that can have human-like functionalities

2. The pitfalls of the traditional AI motivated the development of alernatives

3. CI is a source of biologically inspired problem-solving paradigms

4. Dominant paradigms of CI are: AISs, ANNs, EC, FL and SI

5. CI also has fascinating hybrids of the above paradigms as well

Any Questions?

Thank You