KNOWLEDGE-BASED SYSTEMS

TOPIC 2

Agenda

- What are KBSs?
- Types of KBSs
  - Expert systems
  - Neural networks
  - Case-based reasoning
  - Genetic algorithms
  - Intelligent agents
  - Knowledge-based recommender systems
- Pros and Cons

What are KBSs?

- A knowledge based system is a system that uses artificial intelligence techniques in problem-solving processes to support human decision-making, learning, and/or action.
- Two central components of KBSs are
  - Knowledge base
    - Consists of a set of facts and a set of rules, frames, or procedures
  - Inference engine
    - Responsible for the application of knowledge base to the problem on hand.
- There are pros and cons of using KBSs, compared to human expertise.

Types of KBSs

- Expert systems
- Neural networks
- Case-based reasoning
- Genetic algorithms
- Intelligent agents
- Knowledge-based recommender systems

Expert Systems

- An expert system is a computer program designed to emulate the problem-solving behavior of an expert in a specific domain of knowledge
- In order to qualify as an expert system, a system must have the capability of explaining or justifying its conclusions.
- A system which can explain its reasoning process is said to demonstrate meta-knowledge (knowledge about its own knowledge).

Features of Problem Solvers

- Human experts exhibit certain characteristics and techniques that help them perform at a high level in solving problems in their chosen domain:
  - Solve the problem
  - Explain the result
  - Learn
  - Restructure knowledge
  - Break rules
  - Determine relevance
  - Degrade gracefully

Characteristics of Expert Systems

- The system performs at a level generally recognized as equivalent to that of a human expert or specialist in the field.
- The system is highly domain specific.
- The system can explain its reasoning.
- If the information with which it is working is probabilistic or fuzzy, the system can correctly propagate uncertainties and provide a range of alternative solutions with associated likelihoods.

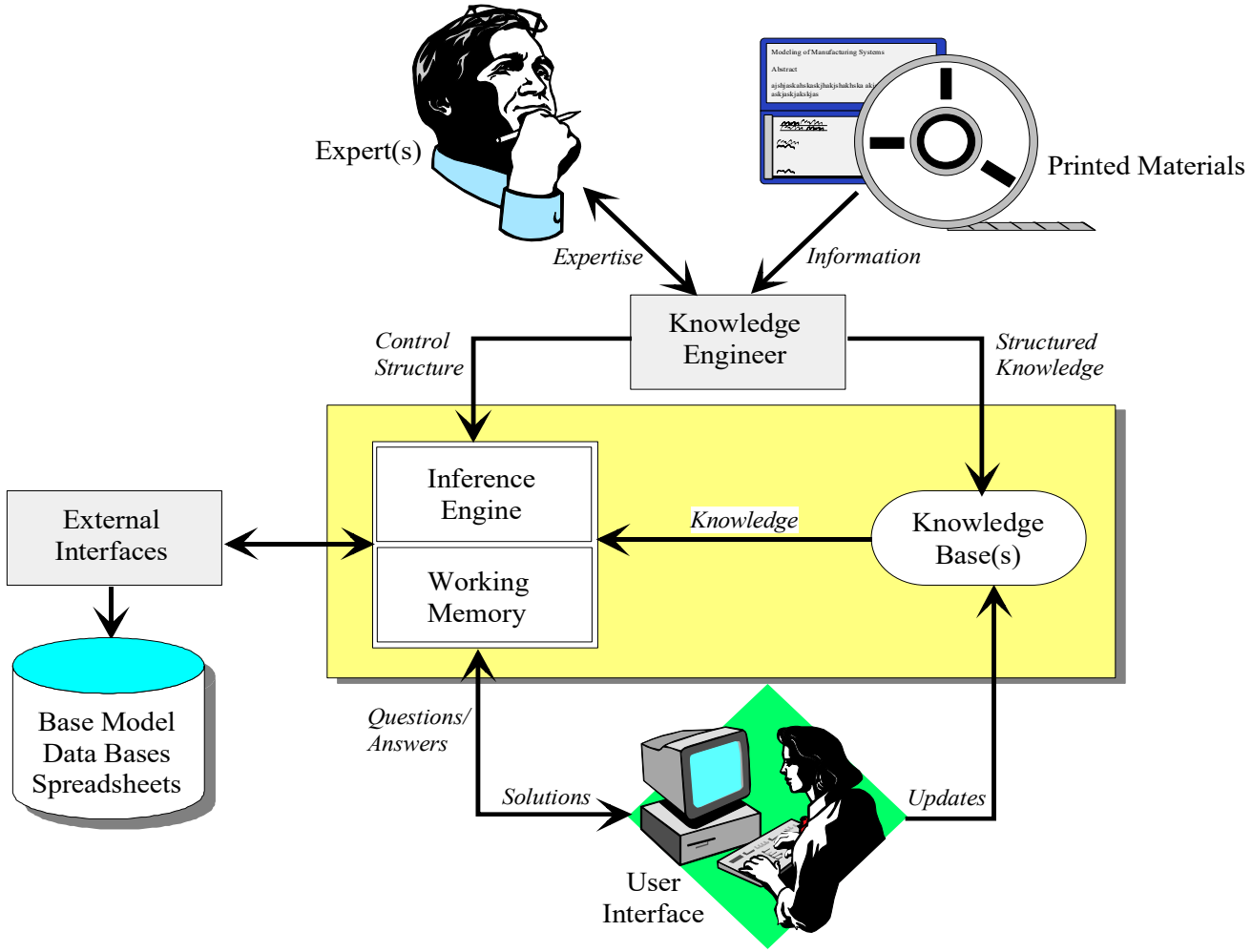
Applications of Expert Systems

- DENDRAL
  - Applied knowledge (i.e., rule-based reasoning)
  - Deduced likely molecular structure of compounds
- MYCIN
  - A rule-based expert system
  - Used for diagnosing and treating bacterial infections
- XCON
  - A rule-based expert system
  - Used to determine the optimal information systems configuration
- New applications: Credit analysis, Marketing, Finance, Manufacturing, Human resources, Science and Engineering, Education, …

Components of Expert Systems

- Knowledge base
  - Consists of facts and rules
  - Rules are commonly expressed in if-then structure (production rules)
    - If-premise then conclusion
    - If-condition then action
- Inference engine
  - Responsible for rule interpretation and scheduling
  - Forward chaining vs. backward chaining
- User interface
- Working memory
- Explanation facility

Conceptual Architecture of a Typical Expert Systems



Expert System Building Tools

- Programming language
  - An expert system can be implemented using a general purpose programming language. However, the programming language LISP and PROLOG are typically used in expert systems implementation, in particular artificial intelligence applications.
- Shells
  - A shell consists mainly of an inference engine and an editor to assist developers in building their knowledge base.
  - Example: CLIPS is an expert system shell developed by NASA

Strengths and Limitations of Expert Systems

- Strengths
  - Human expertise can be expensive
  - Haman advice can be inconsistent
  - Human knowledge may be lost
  - Human knowledge can only be accessed in one place at one time
- Limitations
  - Lack of common sense
  - Lack of inspiration or intuition
  - Lack of flexibility

Neural Networks

- Neural networks represent a brain metaphor for information processing. Neural computing refers to a pattern recognition methodology for machine learning. The resulting model from neural computing is often called an artificial neural network (ANN) or neural network (NN).
- Due to their ability to learn from the data, their nonparametric nature (i.e., no rigid assumptions), and their ability to generalize, neural networks have been shown to be promising in many forecasting and business classification applications.

Basic Concepts of Neural Networks

- The human brain is composed of special cells called nuerons.
- Neural network elements
  - **Nucleus**

    The central processing portion of a neuron
  - **Soma**

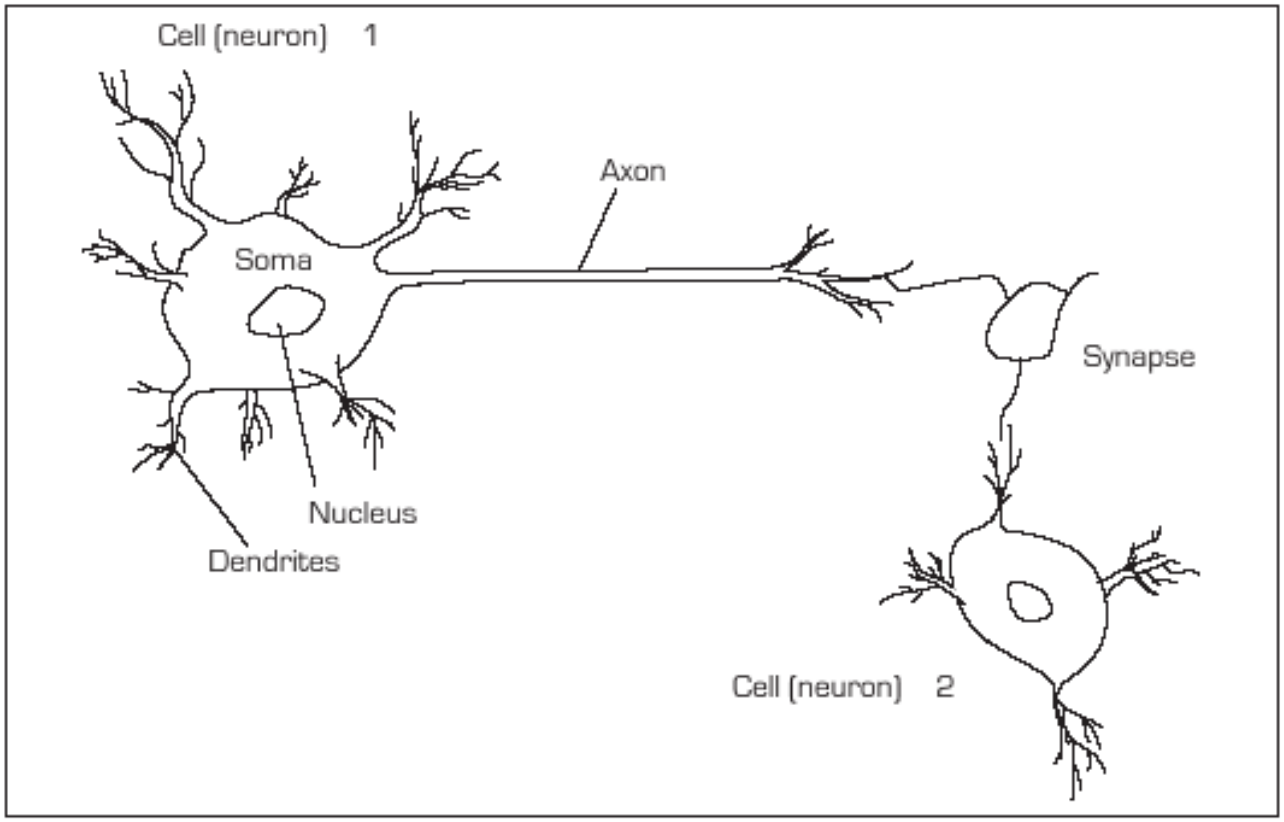
    The main body of the neuron in which the cell nucleus is contained
  - **Dendrite**

    The part of a biological neuron that provides inputs to the cell
  - **Axon**

    An outgoing connection (i.e., terminal) from a biological neuron
  - **Synapse**

    The connection (where the weights are) between processing elements in a neural network

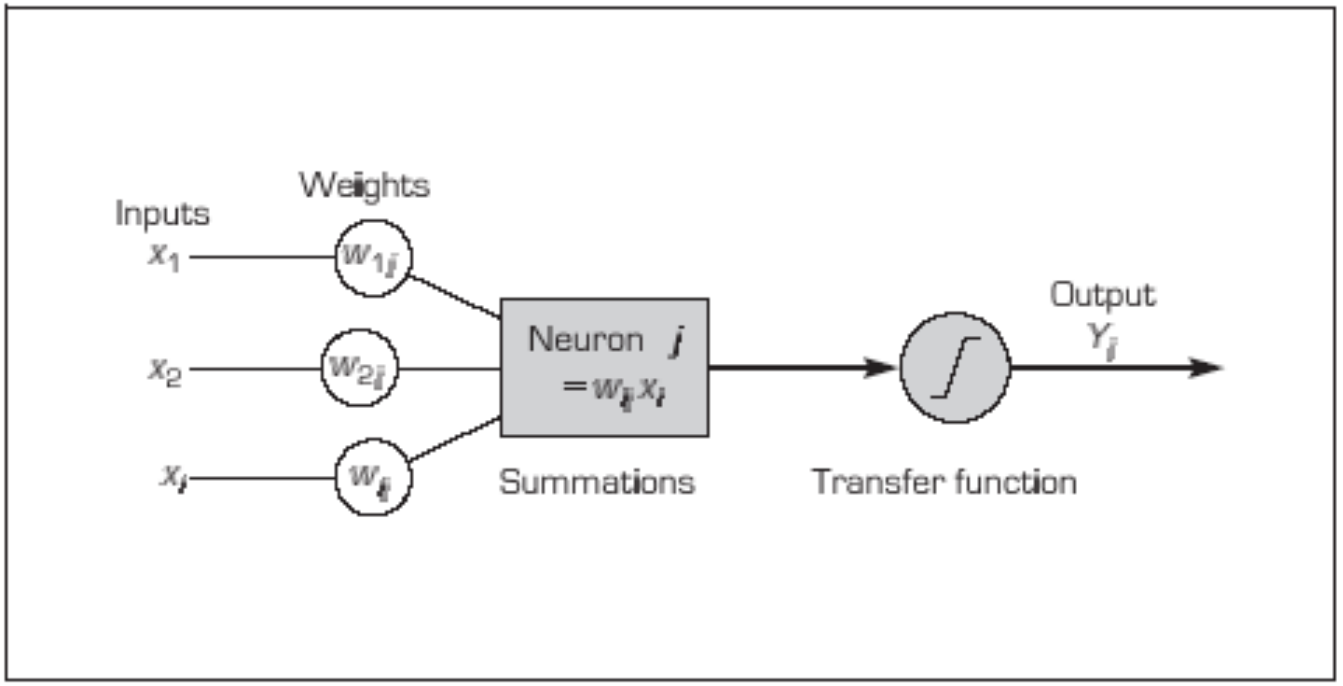
Structure of a Biological Neural Network



Artificial Neural Network

- An ANN model emulates a biological neural network.
- Neural concepts are usually implemented as software simulations of the massive parallel processes that involve processing elements (also called artificial neurons) interconnected in a network structure.
- Connections between neurons have an associated weight.
- Each neuron calculates a weighted sum of the incoming neuron values, transforms this input, and passes on its neural value as the input to subsequent neurons or external outputs.

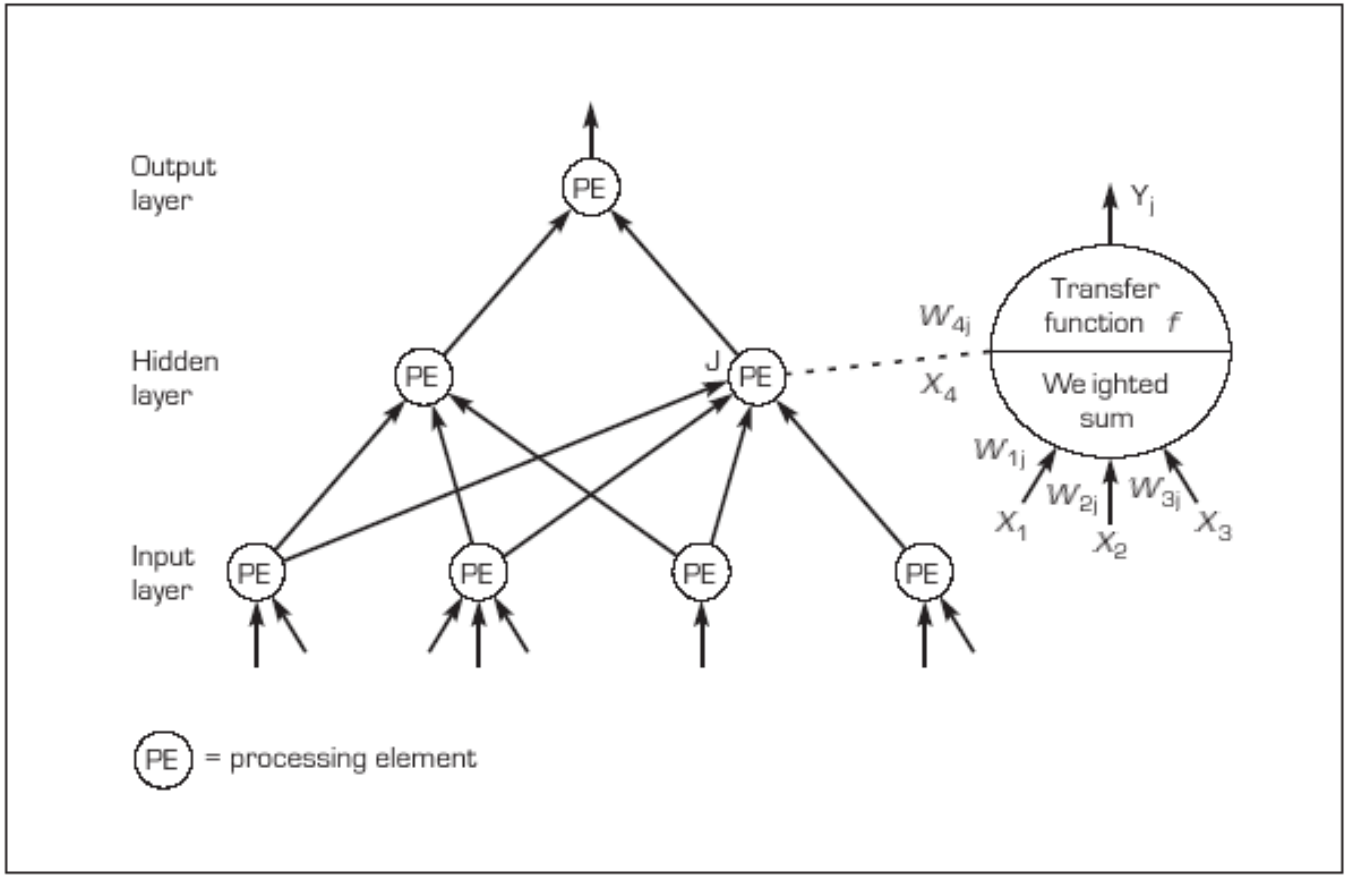
Processing Information in an Artificial Neuron



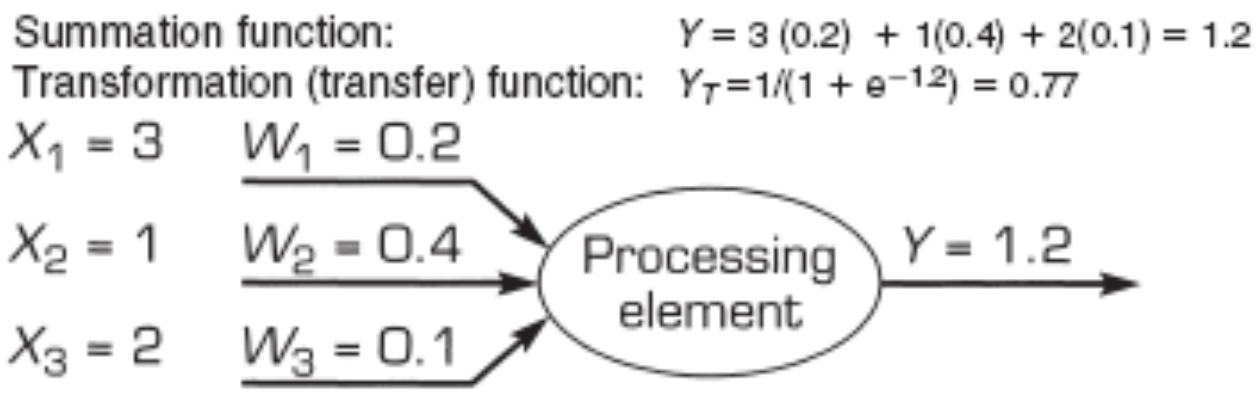
The Relationship Between Biological and Artificial Neural Networks

Biological	Artificial
Soma	Node
Dendrites	Input
Axon	Output
Synapse	Weight
Slow speed	Fast speed
Many neurons (10^9)	Few neurons (a dozen to hundreds of thousands)

Neural Network with One Hidden Layer



Example of ANN Functions



Learning in ANN

- Supervised learning
  - Uses a set of inputs for which the desired outputs are known
  - Example: Backpropagation algorithm
- Unsupervised learning
  - Uses a set of inputs for which no desired output are known.
  - The system is self-organizing; that is, it organizes itself internally. A human must examine the final categories to assign meaning and determine the usefulness of the results.
  - Example: Self-organizing map

Characteristics of ANNs

- Adaptive learning
- Self-organization
- Error tolerance
- Real-time operation
- Parallel information processing

Benefits and Limitations of Neural Networks

- Benefits
  - Ability to tackle new kinds of problems
  - Ability to learn
- Limitations
  - Performs less well at tasks humans tend to find difficult
  - Lack of explanation facilities
  - Requires large amounts of test data

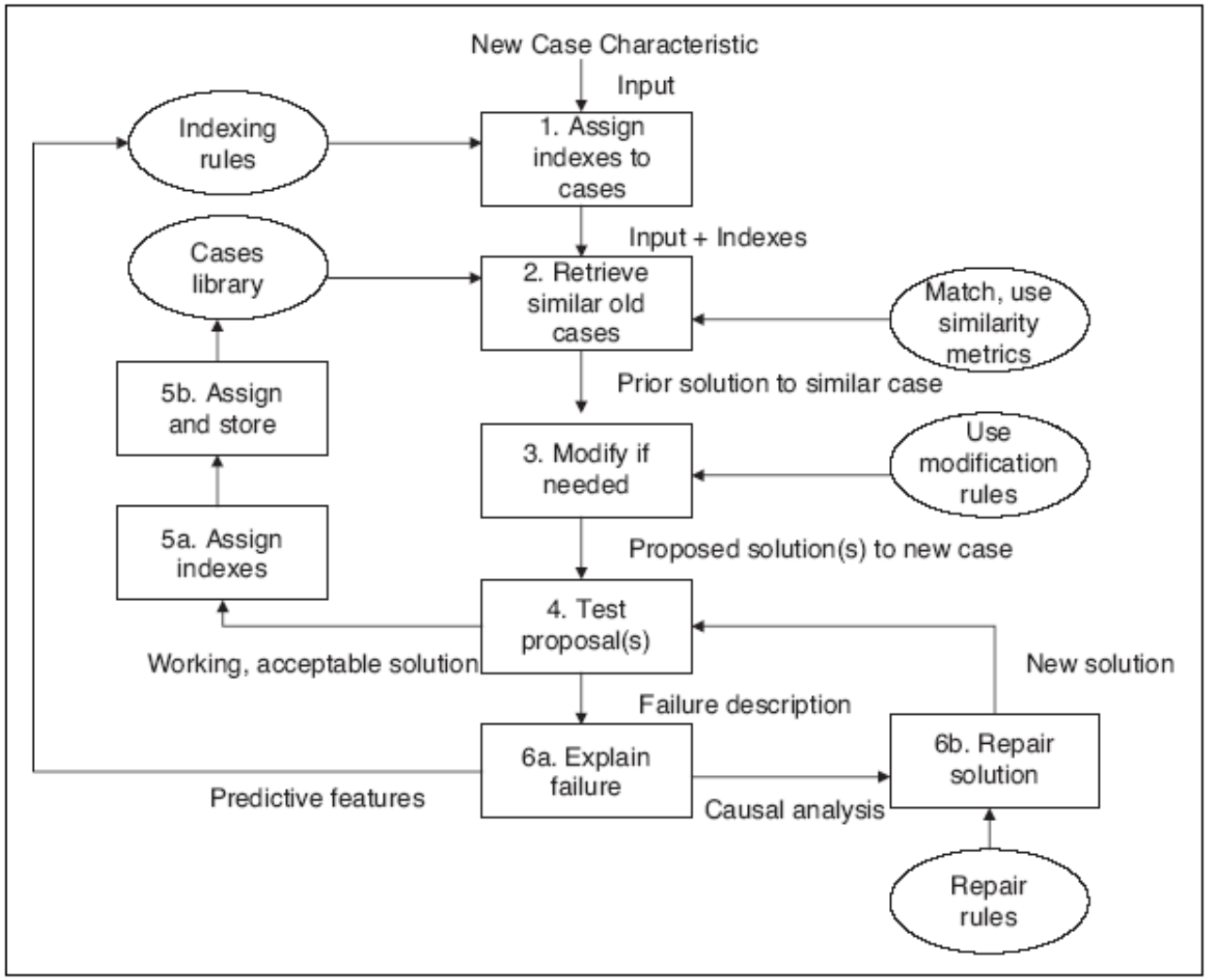
Case-Based Reasoning (CBR)

- A case has two parts: a problem and a solution
- Cases represent experience; that is, they record how a problem was solved in the past
- CBR is a methodology in which knowledge and/or inferences are derived from historical cases. It is based on the premise that new problems are often similar to previously encountered problems and that, past solutions may be of use in the current situations.
- CBR is particularly applicable to problems in which the domain is not understood well enough for a robust statistical model or system of equations to be formulated.

Process of CBR

1. Retrieve
   - Given a target problem, retrieve the most similar cases
2. Reuse
   - Map the solution and reuse the best old solution to solve the current case
3. Revise
   - Test the solution and, if necessary, revise the old case to come up with the solution
4. Retain
   - After the solution has been successfully adapted to the target problem, store the resulting experience as a new case

Step-by-Step Process of CBR



Similarity Computation

- Cases are ranked according to their similarity based on the similarity of each feature
- The degree of similarity can be expressed by a real number between 0 (not similar) and 1 (identical).
- The importance of different features may be different. In that case, similarity is computed by weighted average.
- See Figure 2.16

CBR Examples

- Intelligent customer support and sales support
- Retrieval of tour packages from travel catalogs
- Conflict resolution in air traffic control
- Conceptual building design aid
- Conceptual design aid for electronic devices
- Medical diagnosis
- Aircraft troubleshooting
- Heuristic retrieval of legal knowledge
- Computer supported conflict resolution through negotiation or mediation

Advantages and Disadvantages of Using CBR

- Advantages
  - Improved knowledge acquisition
  - Reduced development time
  - Easier explanation
  - Learning over time
- Disadvantages
  - Storing of cases in the KB.
  - Implicit link between problem and solution
  - Access and retrieval speed

Genetic Algorithms

- Programs that attempt to find optimal solutions to problems by conceptually following steps inspired by the biological processes of evolution
- The method learns by producing offspring that are better and better, as measured by a fitness-to-survive function, until an optimal or near-optimal solution is obtained.

Genetic Algorithm Fundamentals

- **Chromosome**

  A candidate solution for a genetic algorithm

- **Fitness function**

  A measure of the objective to be obtained.

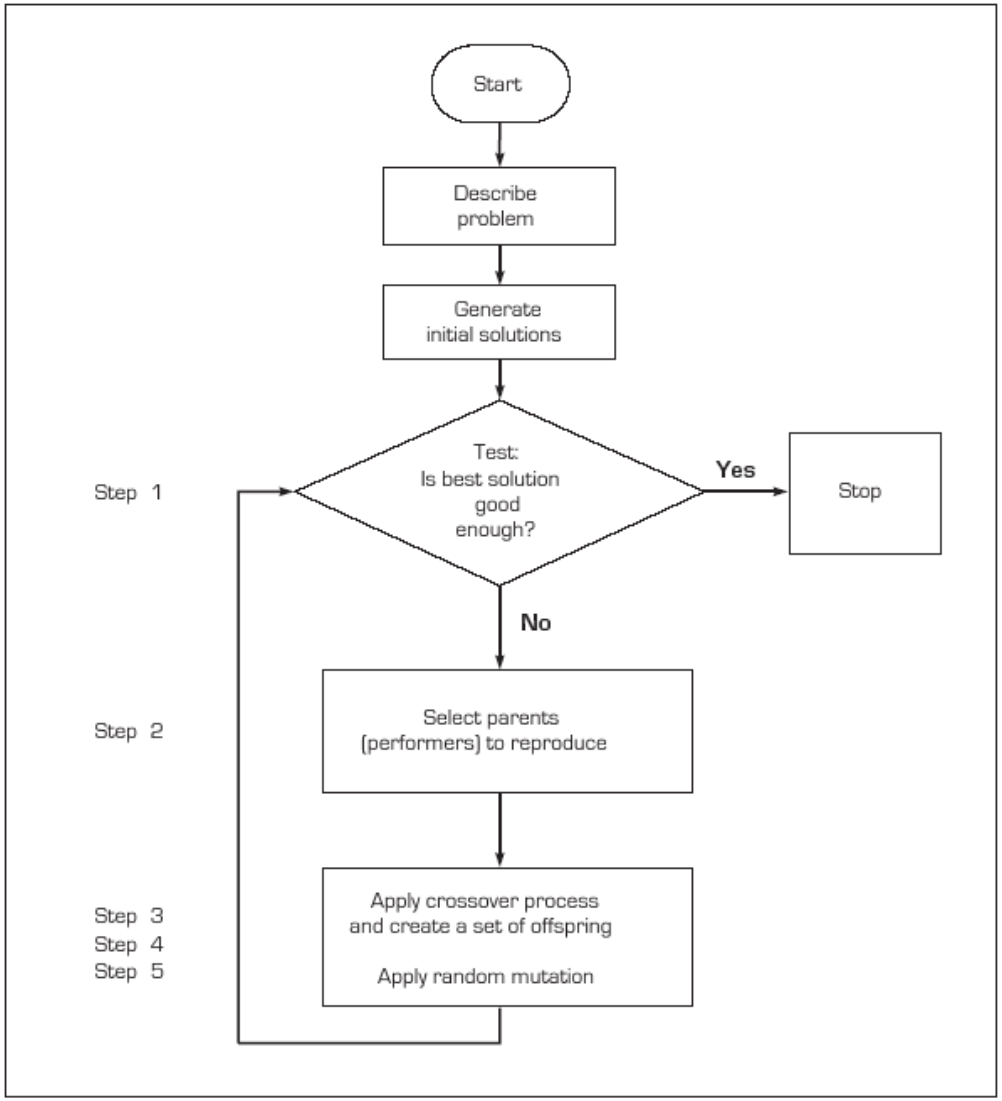
- **Generation**

  An iteration of the genetic algorithmic process in which candidate solutions are combined to produce offspring

Processes within Genetic Algorithm

- **Reproduction**
  - Through reproduction, genetic algorithms produce new generations of improved solutions by selecting parents with higher fitness ratings or by giving such parents a greater probability of being contributors and by using random selection.
- **Crossover**
  - The combining of parts of two superior solutions by a genetic algorithm in an attempt to produce an even better solution
- **Mutation**
  - A genetic operator that causes a random change in a potential solution

Genetic Algorithm Process



Genetic Algorithm Parameters

- Some parameters must be set for the genetic algorithm
  - Number of initial solutions to generate
  - Number of offspring to generate
  - Number of parents and offspring to keep for the next generation
  - Mutation probability
  - Probability distribution of crossover point occurrence
- Their values are dependent on the problem being solved and are usually determined through trial and error

Genetic Algorithm Examples

- Random Walkers
  - https://rednuht.org/genetic_walkers/
- Traveling salesman problem
  - https://towardsdatascience.com/evolution-of-a-salesman-a-complete-genetic-algorithm-tutorial-for-python-6fe5d2b3ca35
- Knapsack problem

Item	1	2	3	4	5	6	7
Benefit	5	8	3	2	7	9	4
Weight	7	8	4	10	4	6	4

Genetic Algorithm Benefits and Limitations

- Genetic algorithms are particularly useful for complex problems that require rapid development of set of good solutions
- Limitations
  - Not all problems can be framed in the mathematical manner that genetic algorithms demand
  - Development of a genetic algorithm is complex
  - In some situations, the "genes" from a few comparatively highly fit (but not optimal) individuals may come to dominate the population, causing it to converge on a local maximum
  - Most genetic algorithms rely on random number generators that produce different results each time the model runs

Genetic Algorithm Applications

- Genetic algorithms provide a set of efficient, domain-independent search heuristics for a broad spectrum of applications including
  - Dynamic process control
  - Complex design of engineering structures
  - Scheduling
  - Transportation and routing
  - Layout and circuit design
  - Telecommunications
  - Discovery of new connectivity typologies

Intelligent Agents

- A computer program that carries out a set of operations on behalf of a user or another program, with some degree of autonomy, and in doing so, employs some knowledge or representation of the user's goals or desires.
- Agents in various forms
  - Software agents (bots), wizards, software daemons, e-mail agents (mailbots), intelligent search agents (Web robots, spiders), Internet softbots, network management and monitoring agents, e-commerce agents, embodied agents, conversational agents

Features of Intelligent Agents

- Reactivity
  - Agents perceive their environment and respond in a timely fashion to changes that occur in it
- Proactiveness
  - Agents are able to exhibit goal-directed behavior by taking initiative
- Social ability
  - Agents are capable of interacting with other agents in order to satisfy their design objectives
- Autonomy
  - Agents must have control over their own actions and be able to work and launch actions independently of the user or other actors

Why Use Intelligent Agents

- The Gartner Group findings on information overload:
  - The amount of data collected by large enterprises doubles every year.
  - Knowledge workers can analyze only about 5% of this data.
  - Most of the knowledge workers' efforts are spent in trying to discover important patterns in the data (60% or more), a much smaller percentage in determining what these patters mean (20% or less), and very little time (10% or less) is spend actually doing something about the patterns.
  - Information overload reduces our decision-making capabilities by 50 percent.
- A major value of intelligent agents is that they are able to assist in searching through all the data.
- Intelligent agents save time by making decisions about what is relevant to the user as well as by automating routine tasks.

Intelligent Agents: How Smart Are They?

- Intelligence levels
  - Level 0 - Agents retrieve documents for a user under straight orders
  - Level 1 - Agents provide a user-initiated searching facility for finding relevant Web pages
  - Level 2 - Agents maintain users' profiles
  - Level 3 - Agents have a learning and deductive component to help a user who cannot formalize a query or specify a target for a search

Intelligent Agents Vs. Expert Systems

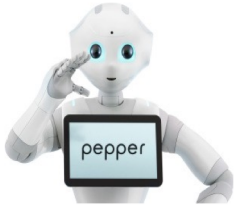
- Agents and expert systems are similar in that they both intend to incorporate domain knowledge to automate decision making.
- They are different in the following aspects:
  - Classic ES are not coupled to any environment in which they act; they act through a user as a middle man. Agents can actively search information from the environment in which they reside.
  - ES are not generally capable of reactive and proactive behavior.
  - ES are not generally equipped with social ability in the sense of cooperation, coordination, and negotiation.

Issues to Consider for Intelligent Agents

- Learning
- Performance
- Multiagents
- Cost justification
- Security and privacy
- Ethical issues
- Acceptance

Conversational Agents

- Conversational agents
  - A software program which interprets and responds to statements made by users in ordinary languages. It integrates computational linguistics techniques with communication over the Internet.
  - Different applications
    - Chatbots
      - Google Duplex (https://www.youtube.com/watch?v=D5VN56jQMWM)
    - Smart speakers
      - Apple HomePod, Google Home, Amazon Echo
    - Conversational robots
      - Sota, Pepper, etc.



Conversational Agents

- Roles of smart speakers

Role	Example Programming Rules
Voice Controller	If I command 'turn on the TV,' then the audio, projector, and screen are turned on.
Automation Hub	If the window is closed and air quality is bad, then the air purifier is turned on.
Reporter	If there is a person inside home after 7am, then weather, temperature, humidity are reported.
Companion	If I enter the house, then a greeting message comes out and lights and TV turn on.