

1 What is Artificial Intelligence (AI):

AI is a branch of computer science devoted to the study of computer designed to imitate the thinking and reasoning power of the human mind.

The definitions of artificial intelligence according to eight recent textbooks are shown in **fig.(1.1)**. These definitions vary along two main dimensions. The ones on top are concerned with thought processes and reasoning, whereas the ones on the bottom address behavior. Also, the definitions on the left measure success in terms of human performance, whereas the ones on the right measure against an ideal concept of intelligence, which we will call rationality. A system is rational if it does the right thing. This gives us four possible goals to pursue in artificial intelligence, as seen in the caption of **fig.(1.1)**.

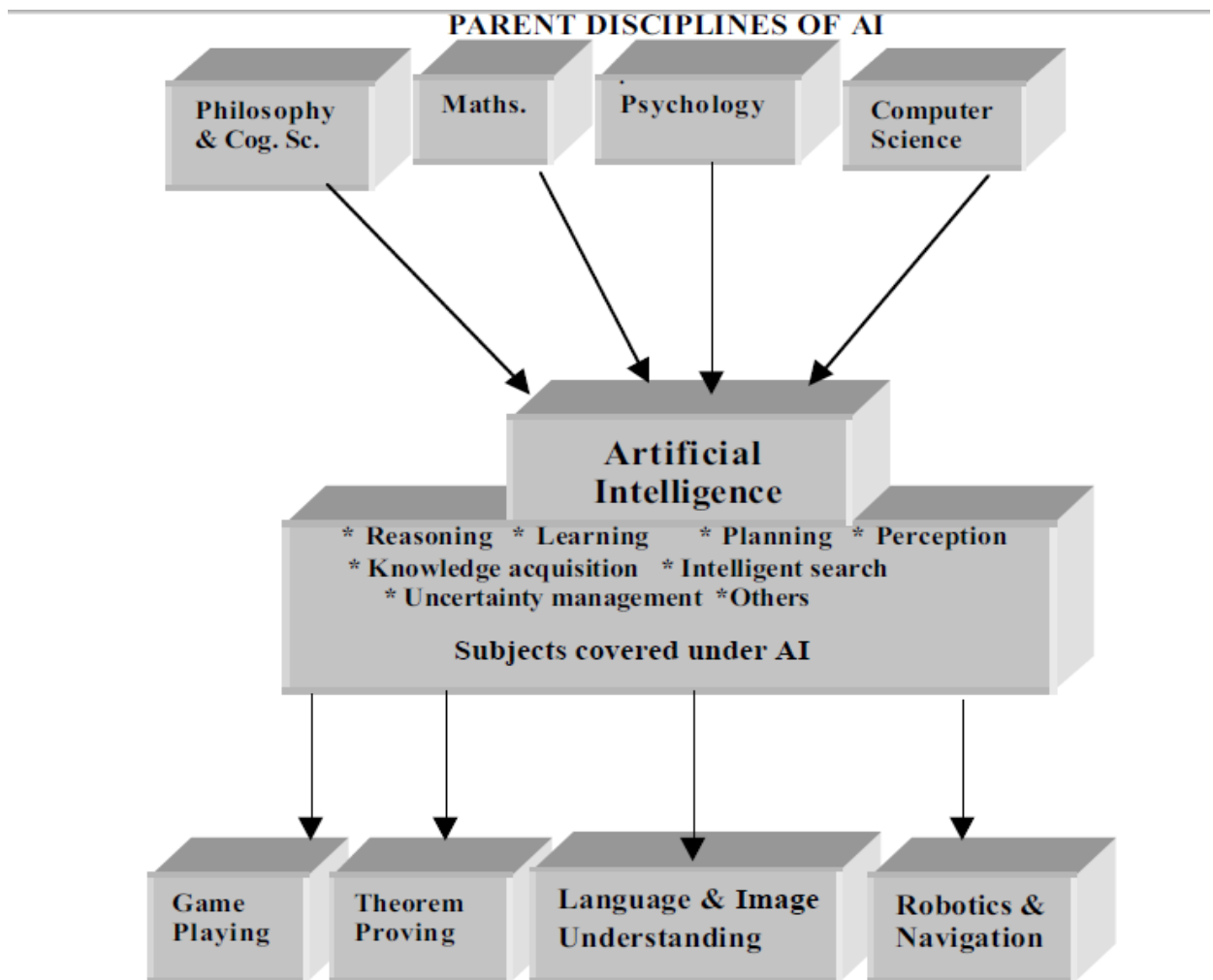
Historically, all four approaches have been followed. As one might expect, a tension exists between approaches centered around humans and approaches centered around rationality. A human-centered approach must be an empirical science, involving hypothesis and experimental confirmation. A rationalist approach involves a combination of mathematics and engineering. People in each group sometimes cast aspersions on work done in the other groups, but the truth is that each direction has yielded valuable insights.

<p>Thinking Humanly "The exciting new effort to make computers think ... <i>machines with minds</i>, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning" (Bellman, 1978)</p>	<p>Thinking Rationally "The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)</p>
<p>Acting Humanly "The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better" (Rich and Knight, 1991)</p>	<p>Acting Rationally "Computational Intelligence is the study of the design of intelligent agents." (Poole et al., 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)</p>

Fig.(1.1): Some definitions of AI (organized into four categories)

1.2 The Disciplines of AI:

The subject of AI spans a wide horizon. It deals with the various kinds of knowledge representation schemes, different techniques of intelligent search, various methods for resolving uncertainty of data and knowledge, different schemes for automated machine learning and many others. Among the application areas of AI, we have *Expert systems*, *Game-playing*, and *Theorem-proving*, *Natural language processing*, *Image recognition*, *Robotics* and many others. The subject of AI has been enriched with a wide discipline of knowledge from Philosophy, Psychology, Cognitive Science, Computer Science, Mathematics and Engineering. Thus in **fig.(1.2)**, they have been referred to as the parent disciplines of AI. An at-a-glance look at **fig.(1.2)** also reveals the subject area of AI and its application areas.



Application Areas of AI

Fig.(1.2): AI, its parent disciplines and application areas.

1.3 The **Subject** of AI

The subject of AI was originated with game-playing and theorem-proving programs and was gradually enriched with theories from a number of parent disciplines. As a young discipline of science, the significance of the topics covered under the subject changes considerably with time. At present, the topics which we find significant and useful to understand the subject are outlined below:

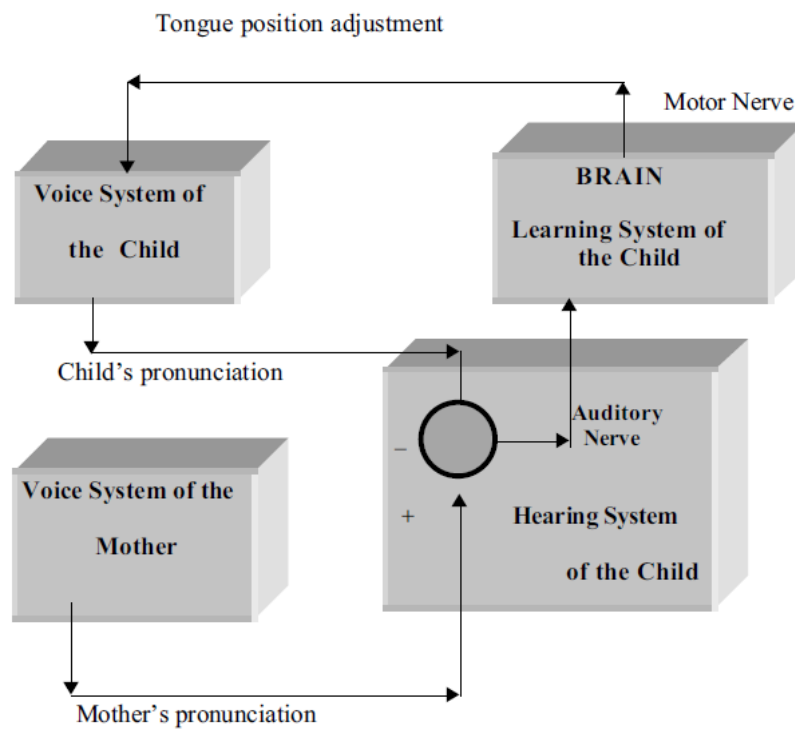


Fig. (1.3): Pronunciation learning of a child from his mother.

[1] Learning Systems: Among the subject areas covered under AI, learning systems needs special mention. The concept of learning is illustrated here with reference to a natural problem of learning of pronunciation by a child from his mother **fig.(1.3)**. The hearing system of the child receives the pronunciation of the character "A" and the voice system attempts to imitate it. The difference of the mother's and the child's pronunciation, hereafter called the error signal, is received by the child's learning system through the auditory nerve, and an actuation signal is generated by the learning system through a motor nerve for adjustment of the pronunciation of the child. The adaptation of the child's voice system is continued until the amplitude of the error signal is insignificantly low. Each time the voice system passes through an adaptation

cycle, the resulting tongue position of the child for speaking "A" is saved by the learning process. The learning problem discussed above is an example of the well-known *parametric learning*, where the adaptive learning process adjusts the parameters of the child's voice system autonomously to keep its response close enough to the "*sample training pattern*". The artificial neural networks, which represent the electrical analogue of the biological nervous systems, are gaining importance for their increasing applications in supervised (parametric) learning problems. Besides this type, the other common learning methods, which we do unknowingly, are inductive and analogy-based learning. In inductive learning, the learner makes generalizations from examples. For instance, noting that "cuckoo flies", "parrot flies" and "sparrow flies", the learner generalizes that "birds fly". On the other hand, in analogy-based learning, the learner, for example, learns the motion of electrons in an atom analogously from his knowledge of planetary motion in solar systems.

[2] Knowledge Representation and Reasoning: In a reasoning problem, one has to reach a pre-defined goal state from one or more given initial states. So, the lesser the number of transitions for reaching the goal state, the higher the efficiency of the reasoning system. Increasing the efficiency of a reasoning system thus requires minimization of intermediate states, which indirectly calls for an organized and complete knowledge base. A complete and organized storehouse of knowledge needs minimum search to identify the appropriate knowledge at a given problem state and thus yields the right next state on the leading edge of the problem-solving process. Organization of knowledge, therefore, is of paramount importance in knowledge engineering. A variety of knowledge representation techniques are in use in Artificial Intelligence. *Production rules, semantic nets, frames, filler and slots, and predicate logic* are only a few to mention. The selection of a particular type of representational scheme of knowledge depends both on the nature of applications and the choice of users.

[3] Planning: Another significant area of AI is *planning*. The problems of reasoning and planning share many common issues, but have a basic difference that originates from their definitions. The reasoning problem is mainly concerned with the testing of the satisfiability of a goal from a given set of data and knowledge. The planning problem, on the other hand, deals with the determination of the methodology by which a successful goal can be achieved from the known initial states.

[4] Knowledge Acquisition: Acquisition (Elicitation) of knowledge is equally hard for machines as it is for human beings. It includes generation of new pieces of knowledge from given knowledge base, setting dynamic data structures for existing knowledge, learning knowledge from the environment and refinement of knowledge. Automated acquisition of knowledge by machine learning approach is an active area of current research in Artificial Intelligence.

[5] Intelligent Search: Search problems, which we generally encounter in Computer Science, are of a deterministic nature, i.e., the order of visiting the elements of the search space is known. For example, in depth first and breadth first search algorithms, one knows the sequence of visiting the nodes in a tree. However, search problems, which we will come across in AI, are non-deterministic and the order of visiting the elements in the search space is completely dependent on data sets. The diversity of the intelligent search algorithms will be discussed in detail later. Logic Programming: For more than a century, mathematicians and logicians were used to designing various tools to represent logical statements by symbolic operators. One outgrowth of such attempts is propositional logic, which deals with a set of binary statements (propositions) connected by Boolean operators. The logic of propositions, which was gradually enriched to handle more complex situations of the real world, is called predicate logic. One classical variety of predicate logic-based programs is Logic Program.

[6] Soft Computing: Soft computing, according to Prof. Zadeh, 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". It, in general, is a collection of computing tools and techniques, shared by closely related disciplines that include fuzzy logic, artificial neural nets, genetic algorithms, belief calculus, and some aspects of machine learning like inductive logic programming. These tools are used independently as well as jointly depending on the type of the domain of applications. The scope of the first three tools in the broad spectrum of AI is outlined below.

✚ Fuzzy Logic: Fuzzy logic deals with fuzzy sets and logical connectives for modeling the human-like reasoning problems of the real world. A fuzzy set, unlike conventional sets, includes all elements of the universal set of the domain but with varying membership values in the interval $[0,1]$. It may be noted that a conventional set contains its members with a value of membership equal to one and disregards other elements of the universal set, for they have zero membership. The most common operators applied to fuzzy sets are AND (minimum), OR (maximum) and negation (complementation), where AND and OR have binary arguments, while negation has unary argument. The logic of fuzzy sets was proposed by Zadeh, who introduced the concept in systems theory, and later extended it for approximate reasoning in expert systems.

✚ Artificial Neural Nets: Artificial neural nets (ANN) are electrical analogues of the biological neural nets. Biological nerve cells, called neurons, receive signals from neighboring neurons or receptors through dendrites, process the received electrical pulses at the cell body and transmit signals through a large and thick nerve fiber, called an axon. The electrical model of a typical biological neuron consists of a linear activator, followed by a non-linear inhibiting function. The linear activation function yields the sum of the weighted input excitation, while the non-linear inhibiting function attempts to arrest the signal levels of the sum. The resulting signal, produced by an electrical neuron, is thus bounded (amplitude limited). An artificial neural net is a collection of such electrical neurons connected in different topology. The most common application of an artificial neural net is in machine learning. In a learning problem, the weights and/or non-linearities in an artificial neural net undergo an

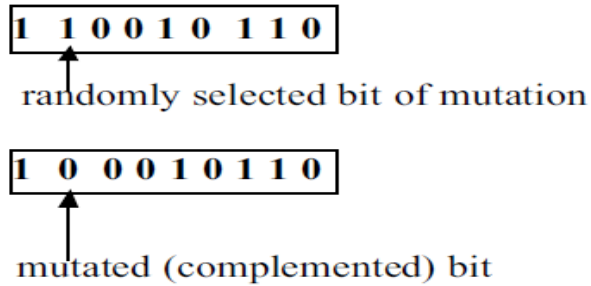


Fig.(1.5): The mutation operation: randomly selected bits are complemented.

[7] Management of Imprecision and Uncertainty: Data and knowledge bases in many typical AI problems, such as reasoning and planning, are often contaminated with various forms of incompleteness. The incompleteness of data, hereafter called **imprecision**, generally appears in the database for:

- i) Lack of appropriate data.
- ii) Poor authenticity level of the sources.

The incompleteness of knowledge, often referred to as **uncertainty**, originates in the knowledge base due to lack of certainty of the pieces of knowledge. Reasoning in the presence of imprecision of data and uncertainty of knowledge is a complex problem. Various tools and techniques have been devised for reasoning under incomplete data and knowledge. Some of these techniques employ:

- i) **stochastic** ii) **fuzzy** and iii) **belief network** models.

In a stochastic reasoning model, the system can have transition from one given state to a number of states, such that the sum of the probability of transition to the next states from the given state is strictly unity. In a fuzzy reasoning system, on the other hand, the sum of the membership value of transition from the given state to the next state may be greater than or equal to one. The belief network model updates the stochastic/fuzzy belief assigned to the facts embedded in the network until a condition of equilibrium is reached, following which there would be no more change in beliefs. Recently, fuzzy tools and techniques have been applied in a specialized belief network, called a **fuzzy Petri net**, for handling both imprecision of data and uncertainty of knowledge by a unified approach