Chapter One: Introduction to Intelligent Systems

By:

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1-1 Introduction

Many definitions of intelligence exist, but for our purposes we use the following: intelligence is the ability to reach one's objectives. A <u>system</u> is more intelligent if it reaches its objectives faster and easier. This includes the ability to <u>learn</u> to do this. The <u>intelligence</u> of a system is a property of its <u>mind</u>. The mind is the functioning of its <u>brain</u>.

A system is part of the universe, with a limited extension in space and time. Stronger or more <u>correlations</u> exist between one part of the system and another, than between this part of the system and parts outside the system.

An intelligent system is a system that has its own main <u>objective</u>, as well as <u>senses</u> and actuators. To reach its objective it chooses an <u>action</u> based on its <u>experiences</u>. It can learn by generalizing the experiences it has stored in its memories.

Examples of intelligent systems are: persons, higher animals, robots, extraterrestrials, a business, a nation.

1-2 What is Intelligence?

Philosophers have been trying for over 2000 years to understand and resolve two *Big Questions* of the Universe: How does a human mind work and Can non-humans have minds?

These questions are still unanswered. In order to think, some*one* or some*thing* has to have a brain, or an organ that enables some*one* or some*thing* to learn and understand things, to solve problems and to make decisions. So, we can define intelligence as *the ability to learn and understand, to solve problems and to make decisions*.

There are many definitions of intelligence. A person that learns fast or one that has a vast amount of experience could be called "intelligent". However, for our purposes the most useful definition is: the systems comparative level of performance in reaching its objectives. This implies having experiences where the system learned which actions best let it reach its objectives.

However, persons are not intelligent in all areas of knowledge; they are only intelligent in those areas where they had experiences.

The goal of *artificial intelligence* (AI) as a science is to make machines do things that would require intelligence if done by humans.

1-3 What is a System?

A system is part of the universe, with a limited extension in space and time. What is outside the frontier of the system, we call its environment. Stronger or more correlations exist between one part of the system and another, than between this part of the system and parts in the environment.

1-4 What is an Intelligent System?

An intelligent system learns how to act so it can reach its objectives. Here is a useful definition of an Intelligent System:

- **It is a system.**
- **It learns during its existence. (In other words, it senses its environment and learns, for each situation, which action permits it to reach its objectives.)**
- **It continually acts, mentally and externally, and by acting reaches its objectives more often than pure chance indicates (normally much oftener).**
- **It consumes energy and uses it for its internal processes, and in order to act.**

What does this definition imply?

- **The system has to exist.**
- **An environment must exist, with which the system can interact.**
- **It must be able to receive communications from the environment, for its elaboration of the present situation. This is an abstracted summary of the communications received by the senses. By communications, in turn, we mean an interchange of matter or energy. If this communication is for the purpose of transmitting information, it is a variation of the flow of energy or a specific structuring of matter that the system perceives.**
- **The Intelligent System has to have an objective, it has to be able to check if its last action was favorable, if it resulted in getting nearer to its objective, or not.**
- **To reach its objective it has to select its response. A simple way to select a response is to select one that was favorable in a similar previous situation.**
- **It must be able to learn. Since the same response sometimes is favorable and sometimes fails, it has to be able to recall in which situation the response was favorable, and in which it was not. Therefore, it stores situations, responses, and results.**
- **Finally, it must be able to act; to accomplish the selected response.**

You can go over the above noted conditions and check, mentally, what would happen if you cancel any one of them. We believe that you will conclude that all are necessary. If anyone is absent the Intelligent System could not function.

1-5 Structure of the Intelligent System

The easiest way to present an overall view of structure is with a representative diagram. We have constructed one for an Intelligent System and present it in figure (1-2).

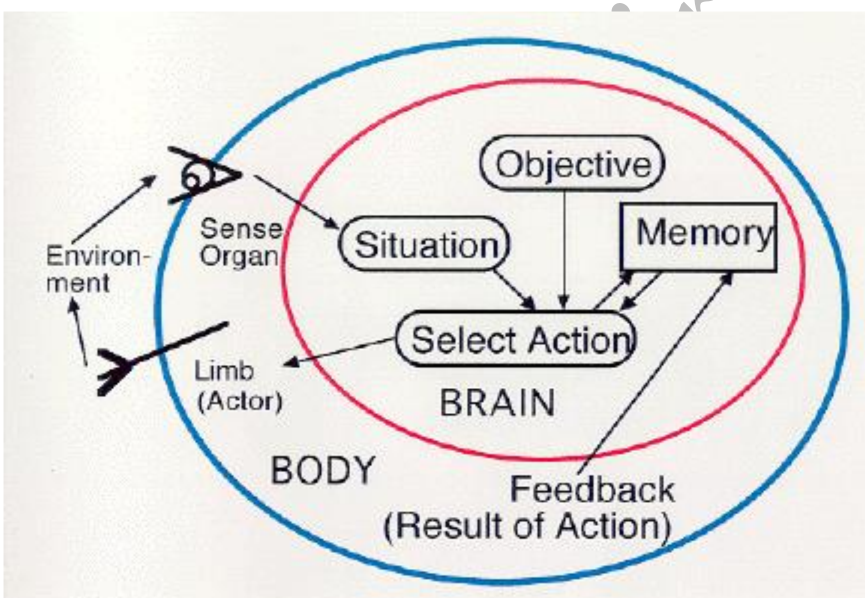

Figure (1-2): The structure of intelligent system.

As you can see from this diagram, the Intelligent System is fundamentally a type of <u>stimulus - response system</u>. The stimulus is the sum of the communications entering through the <u>senses</u>. The <u>brain</u> extracts information from this and represents it as a <u>situation</u>.

Next, the Intelligent System selects a response rule, appropriate to the situation, and performs the response part of this rule. Here we mean by "appropriate" that performing the response permits the system to get nearer to the situation that is its objective.

The Intelligent System makes its selection of response rules from those that it finds stored in its memory. In this memory, the Intelligent System has accumulated response rules that it has generated from earlier experiences and from generalizations based on previously elaborated response rules.

1-6 Details of the Intelligent System

The main processes occurring within the intelligent systems are the following: The Intelligent System has a temporary objective that it has derived from its main objective. It senses its environment, although we have to realize that it has only a few senses and that these can only capture, for instance, light and sound of an object, but cannot capture or know the object itself.

The system then stores these sense impressions as elementary concepts. Concepts are a material way of storing information. Working on concepts it creates new ones and stores relationships to other total, part, abstract and concrete concepts. Of course you realize that there is a difference between an object or occurrence in the environment, the concept the system uses for its internal processing and the word it uses to communicate about the concept. To continue with the internal processes, in more intelligent systems there should now be a check of the incoming information. With all the information, expressed as concepts, the system builds up the present situation. Now it looks into its memory and finds applicable response rules. It chooses one of the best

it has found and performs the corresponding action. Response rules are a field of storage that includes the present situation to which the rule is applicable and the corresponding action.

The intelligent system continually records the present situation and the action that followed as a response rule. The very first response rules are due to chance actions and to teaching.

When the system is externally inactive, that is it sleeps, it reviews the response rules stored in its memory and performs some generalizations. It makes abstractions of concepts and creates the corresponding response rules, including these abstractions. Further comparisons are between the situation and action of a series or recently learned response rules as well as comparisons between situations of different response rules and between actions of different response rules. By all these activities, starting with very concrete response rules, it creates response rules that are applicable to several different but similar situations.

After some while, its memory is full and it forgets the least used concepts and response rules.

1-7 Areas of Application

A major thrust in algorithmic development is the design of algorithmic models to solve increasingly complex problems. Enormous successes have been achieved through the modeling of biological and natural intelligence, resulting in so-called "intelligent systems". These intelligent algorithms include artificial neural networks, evolutionary computation, swarm intelligence, artificial immune systems, and fuzzy systems. Together with logic, deductive reasoning,

expert systems, case-based reasoning and symbolic machine learning systems, these intelligent algorithms form part of the field of Artificial Intelligence (AI). Just looking at this wide variety of AI techniques, AI can be seen as a combination of several research disciplines, for example, computer science, physiology, philosophy, sociology and biology.

1- Neural Networks

A part of the goal of studying Neural Networks is to learn the mechanism of our brain. Neural Network is made up of *neurons* and *synapses.* We have many variants of Neural Networks, based on how neurons are connected. The task is to classify objects. For example,

- **We can recognize handwritten characters by giving pixel values as inputs**
- **We can classify coins inserted into Coke-machine by giving some *features* like diameter and weight of the coin as inputs.**
- **We can identify a jet fighter as enemies by a set of data from radar image.**

All what we have to do is to determine the strength of connection of every synapse called *synaptic weight*. For the purpose, we adjust each of the weight values starting with a set of random values by giving a number of example inputs. This is called a *learning* of Neural Networks, and most popular learning algorithm is called *back propagation.*

2- Evolutionary Computations

To solve a problem, in most cases, means to search for an appropriate set of parameters. For example, when we want to make a neural network classify objects properly, our task is to find out an appropriate configuration of synaptic weights, as we mentioned above.

In Evolutionary Computation, in order for us to be able to solve this kind of problems, it is required, first of all, that we can create a set of candidate solutions at random. This set of random candidate solution is called a *population* of the *1st generation*. Typically, a candidate solution is expressed as a single string of parameters. We call this string *chromosome* and each of its entry *gene*, this is the first condition under which we can solve the problem by Evolutionary Computations. That is, it is necessary to be able to express candidate solution with a single string. The second condition is that we should be able to evaluate the degree to which how good is each of these chromosomes, which is called *fitness evaluation*.

Then we select somewhat of a better two parents' chromosomes than others, and create one child chromosome using biological analogy of crossing their *genes* (crossover) and by replacing some of the genes with other random genes (mutation). This procedure of selecting parents and reproducing children is repeated until the number of children reaches the population. Thus, we can expect better chromosome to appear from generation to generation, and eventually find an optimum chromosome.

3- Fuzzy Logic

The goal of Fuzzy Logic is to design intelligent system based on our human knowledge which can be described by our natural language using so-called IF-THEN rules. A toy example of our knowledge is

- **IF the apple is red THEN buy it OTHERWISE do not buy it.**

Human knowledge or fact in real world, however, is approximate rather than exact, something like

• IF the apple is red THEN it is sweet, possibly sweet-sour, and unlikely to be sour.

Or what would be an answer for

• Now an apple is more or less red then what does the taste seem to be?

In classic logic when we use set theory (which we now call *crisp set*) an element either belongs to a set or not. The apple in the first statement above must either belong to a set RED-APPLE or not. On the other hand, Fuzzy Logic concerns the *degree of belonging* which is expressed using a *membership function* whose value ranges from 0 (no possibility to belong) to 1 (sure to belong), while in crisp set the value is either 1 (belong) or 0 (not belong).

4- Swarm Intelligence

Swarm intelligence (SI) originated from the study of colonies, or swarms of social organisms. Studies of the social behavior of organisms (individuals) in swarms prompted the design of very efficient optimization and clustering algorithms. For example, simulation studies of the graceful, but unpredictable, choreography of bird flocks led to the design of the particle swarm optimization algorithm, and studies of the foraging behavior of ants resulted in ant colony optimization algorithms.

Particle swarm optimization (PSO) is a stochastic optimization approach, modeled on the social behavior of bird flocks. PSO is a population-based search procedure where the individuals, referred to as particles, are grouped into a swarm. Each particle in the swarm represents a candidate solution to the optimization problem. In a PSO system, each particle is "flown" through the

multidimensional search space, adjusting its position in search space according to its own experience and that of neighboring particles. A particle therefore makes use of the best position encountered by itself and the best position of its neighbors to position itself toward an optimum solution.

The effect is that particles "fly" toward an optimum, while still searching a wide area around the current best solution. The performance of each particle (i.e. the "closeness" of a particle to the global minimum) is measured according to a predefined fitness function which is related to the problem being solved. Applications of PSO include function approximation, clustering, optimization of mechanical structures, and solving systems of equations.

Studies of ant colonies have contributed in abundance to the set of intelligent algorithms. The modeling of pheromone depositing by ants in their search for the shortest paths to food sources resulted in the development of shortest path optimization algorithms.

Other applications of ant colony optimization include routing optimization in telecommunications networks, graph coloring, scheduling and solving the quadratic assignment problem. Studies of the nest building of ants and bees resulted in the development of clustering and structural optimization algorithms.

5- Artificial Immune Systems

The natural immune system (NIS) has an amazing pattern matching ability, used to distinguish between foreign cells entering the body (referred to as *non-self*, or *antigen*) and the cells belonging to the body (referred to as *self*). As the NIS encounters antigen, the adaptive nature of the NIS is exhibited, with

the NIS memorizing the structure of these antigen for faster future response the antigen.

In NIS research, four models of the NIS can be found:

- **The classical view of the immune system is that the immune system distinguishes between self and non-self, using lymphocytes produced in the lymphoid organs. These lymphocytes "learn" to bind to antigen.**
- **Clonal selection theory, where an active B-Cell produces antibodies through a cloning process. The produced clones are also mutated.**
- **Danger theory, where the immune system has the ability to distinguish between dangerous and non-dangerous antigen.**
- **Network theory, where it is assumed that B-Cells form a network. When a B-Cell responds to an antigen, that B-Cell becomes activated and stimulates all other B-Cells to which it is connected in the network.**

An artificial immune system (AIS) models some of the aspects of a NIS, and is mainly applied to solve pattern recognition problems, to perform classification tasks, and to cluster data. One of the main application areas of AISs is in anomaly detection, such as fraud detection, and computer virus detection.

Note:

The first three sub-branch of AI are also known as *Soft Computing (SC)* –the fusion of methodologies designed to model and enable solutions to real world problems, which are not modeled or too difficult to model mathematically. The aim of Soft Computing is to exploit the tolerance for imprecision, uncertainty, approximate reasoning, and partial truth in order to achieve close resemblance with human like decision making.

The above five sub-branch of AI are also known as *Computational Intelligence (CI)* – the study of adaptive mechanisms to enable or facilitate intelligent behavior in complex and changing environments. These mechanisms include those AI paradigms that exhibit an ability to learn or adapt to new situations, to generalize, abstract, discover and associate.