UNIT 1 INTRODUCTION TO INTELLIGENCE AND ARTIFICIAL INTELLIGENCE

Structure **Page Nos.**

1.0 INTRODUCTION

In this unit, we discuss intelligence, both machine and human. However, as our subject matter in the course is machine intelligence, or artificial intelligence, our discussion of the subject matter is mainly from the point of view of machine intelligence. Machine intelligence is popularly known as *Artificial Intelligence and is generally referred to by its abbreviation viz.* **AI.** We also shall use the name AI for the discipline throughout. The style of discussion in this unit is to start with a definition of AI by some pioneer in the field, and then elaborate the ideas involved in the definition. Further, while elaborating the ideas involved in the definition, we introduce a number of relevant new ideas, concepts and definitions to be used later. In this process, we have introduced and/or explained the following:

i) Artificial Intelligence & Human Intelligence
ii) When a problem necessarily requires parallel processing for its solution
iii) Symbol vs. number issue
iv) Numeric vs. symbolic processing
v) Algorithm vs. non-algorithmic method and limitation of algorithmic approach
vi) Limitations of computational abilities of logical devices
vii) Heuristics – an important A.I technique
viii) Time/space complexities of programs and problems, exponential time vs. polynomial time, hard problems
ix) Role of search and knowledge in solving hard problems; search as an important AI technique
x) Enumeration of issues about knowledge
xi) Information: one of the four fundamental properties of nature
xii) Organisation; relations between information and organisation and between information and intelligence
xiii) A principle of intelligence
AI as a science and as an engineering discipline
xiv) Controversial issue about the possibility of machine intelligence at least equating or surpassing human intelligence.
xv) Brief history of AI … the name and as a subject

1.1 OBJECTIVES

After going through this unit, you should be able to:

- discuss the concepts of 'intelligence' and artificial intelligence' as visualised by a number of leading experts in the field;
- enumerate the fields in which human beings are still better than computers;
- tell the difference between the concepts of:
  - (i) Symbol and number
  - (ii) Algorithmic and non-algorithmic methods
  - (iii) Information and knowledge
  - (iv) Polynomial time and exponential time complexities
- tell the relation of *information* to *organisation* and to *intelligence.*

1.2 SOME SIMPLE DEFINITIONS OF A.I.

Before looking at what A.I. is in the expert's opinions that involve technical terms needing some explanation, we state below three simple definitions from completely non-specialists' point of view:

1. A.I. is the study of making computers smart.

2. A.I. is the study of making computer models of human intelligence; and finally

3. A.I. is the study concerned with building machines that simulate human behaviour.

The **first one** of the above definitions is based on **behaviour-oriented** approach to A.I. According to this approach, AI is concerned with programming computers *to behave* intelligently. The **next definition** is more from a **psychologists** point of **view,** where the purpose is to use computer as a tool to understand better the *mechanisms of the human mind,* and the **final definition,** which we may call **robotic approach to A.I.,** includes under the domain of A.I., not only writing of computer programs but *building also* the whole of an intelligent system or *machine including its mechanical, electronic, optical components and other components*.

In order to have still better and concrete opinion about what is AI and its subject-matter, we consider definitions suggested by leading writers and pioneer contributors to the development of A.I. We supplement these definitions with comments to facilitate the understanding of the underlying ideas and of the technical terms involved in the definitions.

1.3 DEFINITION BY ELIANE RICH

Definition 1: The first definition we consider is **by Elaine Rich,** the author of the book entitled '*Artificial Intelligence*'[1]. **It states: Artificial Intelligence is the study of how to make computers do things, at which, at the moment, people are better**.

Comment 1, Definition 1: Implicit in the Rich's definition is the idea that there are mental tasks that computers can do better than human beings and *vice-versa*, there are tasks which *at the moment* human beings can do better than computers. It is well-known that **computers are better than human beings** in the matter of

- *numerical computation,*

- *information storage, and*
- *repetitive tasks*.

On the other hand, at the moment, **human beings are much better than machine** in the matter of

- *understanding* including the capability of explaining,
- predicting the behaviour and structure of a system,
- in the matter of *common-sense reasoning,*
- in drawing conclusions when available information is either incomplete, inconsistent or even both, and
- also, in visual understanding and speech understanding, which require simultaneous availability (availability in parallel) of large amount of information.

In essence, it is found that **computers are better than human beings in tasks requiring sequential but fast computations,** where **human beings are better than computers in tasks, requiring essentially parallel processing.** In order to clarify what it is for a problem to essentially require parallel processing for its solution, we **consider the following problem:**

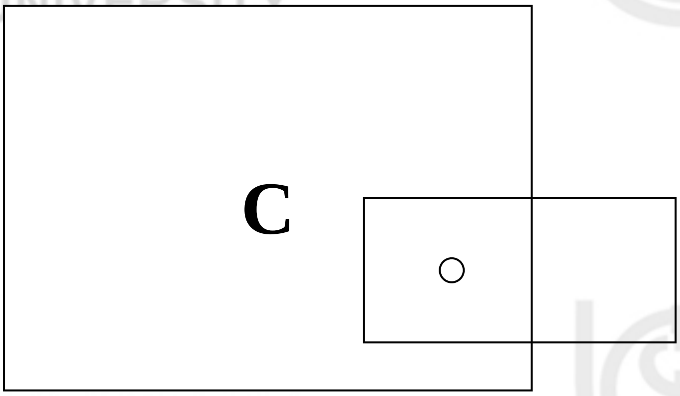
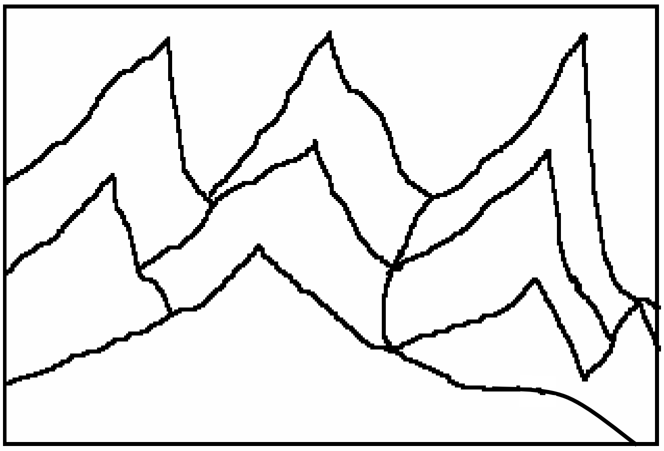


Figure 1.1

We are given a paper with some letter, say, C written on it and a card-board with a pin-hole in it. The card board is placed on the paper in such a manner that the letter is fully covered by the card board as shown in *Figure 1.1*. We are allowed to look at the paper only through the pin-hole in the card-board. The problem is to tell correctly the letter written on the paper by just looking through the pin-hole. As the information about the black and white pixels is not available simultaneously, it is not possible to figure out the letter written on the paper. The figuring out the letter on the paper requires, simultaneous availability of the whole of the grey-level information of all the points constituting the letter and its surrounding on the paper. The gray-level information of the surrounding of the letter provides the context in which to interpret the letter.

We consider another example that shows the significance of contextual information or knowledge and its simultaneous availability for visual understanding. From the following picture, we can conclude that one of the curved lines represents a river and other curved lines represent sides of the hills only on the basis of the simultaneous availability of information of the pixels.



Contextual information plays a very important role not only in the visual understanding but also in the language and speech understanding. In case of speech understanding, consider the following example, in which the word '*with*' has a number of meanings (or connotations) each being determined by the context.

- Mohan saw the boy in the park ***with*** a telescope.
- Mohan saw the boy in the park ***with*** a dog.
- Mohan saw the boy in the park ***with*** a statue.

Further, the phrase '*for a long time*' may stand for a few hours to millions of years, but again determined by the context, as explained below.

For a long time…..

- He waited in the doctor's room *for a long time*.
- It has not rained for *a long time*.
- Dinosaurs ruled the earth for *a long time*.

Comment 2, Definition 1: In addition to the advantage that human beings have in the matter of parallel processing as explained above, **Boden [12]** says: *humans have two psychological strengths which are yet to be approached by computer systems: a teeming richness of conceptual sources and the ability to evaluate new ideas in many different ways. The first of these is difficult enough for AI to emulate, the second is even more problematic*.

Comment 3, Definition 1: The definition is rather weak in the sense that it fails to include some areas of potentially large importance viz, problems that can be solved at present neither by human beings nor by computers. Also, it may be noted that, by and by, if computer systems become so powerful that there is no problem left, which human beings can solve better than computers, then nothing is left of AI according to this definition.

1.4 DEFINITION BY BUCHANIN AND SHORTLIFFE

Next, we consider a definition obtained by rephrasing and combining the two definitions, viz., the first by **Bruce G. Buchanin** as given in '*Encycolopedia Britanica'* and the second by **BUCHANIN & SHORTLIFFE** as given in *Rule-Based Expert Systems [2]*. **It states:**

Definition 2 AI is the branch of computer science that deals with *symbolic* rather than numeric processing and *non-algorithmic* methods including the *rules of thumb or heuristics* instead of *algorithms* as *techniques* for solving problems.

Comments/Explanations 1, Definition 2: Symbolic processing vs numberic processing: We generally think and use 128 as a *number* which has a definite relation with the number say 105 *(that of greater than)*, also with 64 *(that of being double of)* and again with 2 *(that of being a multiple of)*. Also, 128 can be multiplied, through *built-in mechanisms*, with any number say 3 to get 384. However, *if* the numbers mentioned above including 128 denote the *route numbers of buses or house numbers a residential colony then none of the relations or operations mentioned above, may hold*. Rather, in this context, these relations of 128 w.r.t. 105, etc. and the operations like multiplication even *do not make any sense*. We cannot tell what is meant by saying '*House Number 128 is greater than House Number 105*' in a normally acceptable way.

On the other hand, *even a non-digital character sequence say 'ABC' may represent a number*, for example, in hexadecimal number system. Also, words of English (or any other) language *when considered lexicographically ordered, acquire some numeric attributes*.

The conclusion we draw from the above discussion, is that a word as a sequence of characters (including digits) may denote a number or a symbol (**henceforth, a symbol stands for non-numeric symbol)** depending upon the *context* in which it is used. *And the context is determined by the nature of the problem under consideration*. If the problem can be solved using only numerical aspects of the objects in the domain and environment of the problem, then we have the advantage of having *built-in relations* (like less than, equal to etc.) and the *built-in operations* (like +, -, * etc.) that can be readily used without having to define these relations and operations explicitly.

But, unfortunately, most of the problems, we encounter for our day to day survival or even for our intellectual pursuits, involve *not only quantitative, but qualitative aspects also of the objects* of the problem domain. In order to solve these problems, we use *common sense reasoning, exploit our capability for visual and linguistic understanding, try to get meaning out of incomplete and even inconsistent information that is available*, in addition to a number of other known and unknown mechanism. **Qualitative aspects**, their ideal representations, defining relations and operations involving these aspects, are generally different for different types of problems. Hence, it is impossible to capture in general relevant relations and operations for all types of problems, and then defining these as built-in operations of the machine, because there are potentially infinite types of problems that we encounter and try to solve.

This discussion explains the basic difference between numeric processing and (non-numeric) symbolic processing. Summarizing, **numeric processing involves only** a small number of well-defined relations and operations having universally accepted meanings, and hence, these relations and operations can be incorporated as a part of a computer system. On the other hand, **in symbolic processing** the relations and operations required to solve a problem *depend upon* the problem under consideration, and hence, have to be defined explicitly along-with or as a part of programs constituting the solutions of the problems.

The weakness of numeric processing, however, is that it can be used in solving a small fraction of the set of problems we want to or need to solve. The numeric processing can be used in solving only those problems, the solutions of which involve only *numeric aspects* of the objects involved in the domain and environment of the problem under consideration. For the solution of other solvable problems, we need to use *symbolic processing*. It is not out of place to mention **that not all problems which even can be stated precisely or formally, are amenable to computer solutions using even symbolic processing.** More discussion in this respect follows next, under Comments/Explanations 2 for Definition 2.

Comments/Explanation 2, Definition 2 : Algorithmic method vs non-algorithmic method, heuristics : We recall that an **Algorithm** is a step-by-step procedure with well-defined starting and ending points, which is guaranteed to reach a solution to a specific problem. A solution to a problem which can be expressed as an algorithm is called an *algorithmic solution*. An algorithmic solution may involve only numeric processing or may involve symbolic processing with/without numeric processing. *For the purpose of further discussion, 'symbolic processing' includes/subsumes numeric processing*. **Algorithmic approach even when using symbolic processing has limitations. During 1930's, a number of logicians and mathematicians including Gödel, Church, Post, Turing and Kleene suggested a number of mathematical models of a computer, and through these models tried to explain the nature of computation, established a number of useful results about computation and also found the limits of computational power**.

They proved that even through a problem may be expressed precisely *or formally (i.e., in terms of mathematical entities like sets, relations functions etc.)*, yet it need not yield to an *algorithmic* solution. A problem which has at least one algorithmic solution is called a **solvable problem**. They further proved that out of even solvable problems, only a small fraction can be solved if only *feasible amount* of resources like, time and space are used. Informally, **feasible amount** of resources means that the requirement for resources does not increase too rapidly with the increase in *size* of the problem. The notion of the **size of a problem** will be defined formally later on (*under comment 1 on Definition 3*). However, an *intuitive idea about the concept of the size of a problem* and its role in estimating the resource requirement for solving the problem can be had through the simple problem of calculating income tax for each of the tax-payers. The requirement of resources like, time and computing equipment for *1000 tax-payers* would be much less, as compared to the requirement of resources for computing income-tax for *one million tax* payers. In this problem, *n, the number of tax-payers for whom the income-tax is to be calculated, may be taken as size of the problem*.

This limitation and other difficulties with algorithmic solutions has given impetus to efforts for finding non-algorithmic solutions of problems. **Neural Network approach** to solving many difficult problems, is a well-known **alternative to algorithmic methods** of solving problems. In AI, there are mainly two approaches to solve problems, which generally difficult to solve with algorithmic methods. One approach is Neural approach, mentioned just above. The other approach is called symbolic approach. The symbolic approach cannot be said to be non-algorithmic. The main difference between symbolic approach of AI and algorithmic approach is that symbolic approach of AI emphasizes exploitation of the knowledge of the domain and the environment of the problem under consideration. Some of this knowledge is in the form rules of thumb, generally, called heuristics in AI.

In order to realise **the limitations of algorithmic approach to solving problems,** we need not refer to highly theoretical work by the earlier mentioned logicians/mathematicians. *The limitation of the approach may be appreciated through the following simple example*.

Consider the problem of crossing from one side over to the other side of a busy road on which a number of vehicles are moving at different velocities. A step-by-step (i.e., algorithmic) method of solving this problem may consist of:

(i) Knowing (exactly) the distances of various vehicles from the path to be followed to cross over.
(ii) Knowing the velocities and accelerations of the various vehicles moving on the road within a distance of, say, one kilometer.
(iii) Using Newton's Laws of motion and their derivatives like $s = ut + \frac{1}{2}at^2$, and calculating the times that would be taken by each of the various vehicles to reach the path intended to be followed to cross over.
(iv) Adjusting dynamically our speeds on the path so that no collision takes place with any of the vehicle moving on the road.

The above is a systematic step-by-step method, i.e., *an algorithm*, of crossing the road that may ensure no collision with any vehicle. But, how many of us can follow it? Hardly anybody! *First of all*, it is practically impossible to measure distances, velocities and accelerations of various vehicles on the road, even within a radius of one kilometer. *Secondly*, even if we assume theoretically that it is possible to measure distances, velocities and accelerations of various vehicles and to calculate safe timings to cross the road, we would not like or care to follow the above-mentioned algorithm, because *our past experience*, our sense of survival and other built-in mechanisms have allowed us, in the past, to cross over safely without following any *systematic method*. All of us just *guess* the distances of the vehicles, safe enough to cross over, and then actually cross over at an appropriate time. Not even one in 1000, on an average gets hurt when crossing a road using only guesses, in a crowded city like, Delhi, where movement of vehicles is one of the most chaotic and unruly in the whole world. However, *this is not to deny that once in a while, the guess is incorrect and someone or other gets hurt or even is killed almost every day*.

Each one of us every day, comes across hundreds of problems similar to the one of crossing of a road. And, for each such problem one uses a good guess and one generally is able to solve the problem satisfactorily each time, though the solutions may not be the best possible ones. And, or once in a while, we even fail to get any solution using the guess. However, if we insist on only following a systematic step-by-stop method that guarantees best possible solution for solving each problem, then we would hardly be able to make any progress in our day to day business of even mere survival.

The essence of the above discussion is that while attempting solutions of many of the problems, it is not only desirable but almost essential that for each of such problems we follow some **good guess instead of following a step-by-step systematic method** that guarantees the best solution. In **A.I, these guesses are called heuristics.** In later chapters, we discuss heuristics in detail. However, for the time being, we state that **heuristics** *are good guesses, possibly based on past experience, judgement, intuition or hunches, which lead us most of the time to reasonably good solutions, though these guesses do not guarantee the best solutions or even any solution for every instance of the problem under consideration*.

The advantage of using heuristics is that we do not have to rethink completely everytime we are faced with a problem of the type of which another problem has already been solved satisfactorily. If we have a *handy rule of thumb* that may apply to the current problem, it may suggest to us how to proceed.

1.5 ANOTHER DEFINITION BY ELAINE RICH

The next definition, again **by Elaine Rich [1]** is more technical and involves some concepts from Theory of Computation. **It sates:**
Definition 3: Artificial Intelligence is the study of techniques for solving exponentially hard problems in polynomial time exploiting knowledge about the problem domain.

Comments/Explanations 1, Definition 3: For deeper understanding of the concepts like *hard, solvable and unsolvable problems*, any one of the books by Brady [3], by Lewis and Papadimiriou [4] or by Hopcroft and Ullman [5] may be consulted. However, for our purpose of appreciating Definition 3 of A.I., we briefly discuss only the required essentials from Theory of Computation (TOC). In the comments on Definition 2, we have already talked about the mathematical models of computation and also about the limitations of algorithmic solutions.

As computer study is partly engineering in nature, in the sense that we design and implement or produce computer solutions for different types of problems and hence these products, i.e., solutions, need to be evaluated *vis-a-vis* problem specifications and other measures like, efficiency in respect of time and space requirements of the solutions. In order to measure the efficiency of a suggested computer solution of a problem, the earlier mentioned logicians/mathematicians suggested the concepts of ***time complexity*** and ***space complexity*** for the solutions and even for the problems. The basic idea behind these complexity measures is that all the operations that a computer (present or future generations) can execute, may be thought of as composed of a *small number of* basic operations. These basic operations can be easily compared for their relative requirements for time and space. For the basic operation say $O_{1,}$ which is expected to take minimum time (or space) among all the basic operations, the time (or space) complexity is assigned the number one. For any other basic operation, complexity is a positive number depending upon the expected relative requirement for time (or space) for the operation as compared to that for the operation O_1. For other computer operations, time/space complexity may be computed from those for the basic operations. Also from these complexities, we can compute the complexities of the programs using the size of the input data as an additional parameter. For example, to multiply two n x n matrices we require n^3 multiplications and $(n^3 - n^2)$ additions.

Thus, complexity of the straight-forward method of multiplication of two n x n matrices is $n^3 . \beta + (n^3 - n^2) \alpha$, where α and β are complexities of, respectively, the operations of addition and that of multiplication of two numbers. The time/space complexity of a **problem** may be defined as the time/space complexity of the program which has the least complexity among all the known programs that solve the problem. Further, a problem is said to be **polynomial time problem,** if the time complexity of the problem is some polynomial $a_0 n^k + a_1 n^{k-1} + \dots + a_i n^{k-i} + \dots + a_{k,}$ where n is the size of the data. Similarly, **exponentially hard problem** is one for which time complexity is of the form a^n, with a > 1. For large n, the value of an exponential function increases at a much faster rate than the increase in the value of any given polymial functions in n. For a given polynomial function f(n) and an exponential function g(n), it is always possible to find a positive integer k such that g(n) > f(n) for all intergers $n \geq k$. Thus, the problems requiring exponential time are considered harder than the problems requiring polynomial time. '**Polynomial time' is considered as *reasonable* amount of time**, and on the other hand, **'exponential time' is considered as *impractical or infeasible* amount of time from computational point of view.** This is why, the problems requiring exponential time are considered as **hard** problems. Also, using the fact that the complexity of a problem is the least of the complexities of its known algorithms, we can not solve an exponential time problem in polynomial time.

Comment 2, Definition 3: Role of knowledge in solving hard problems:

In view of the previous comments, no polynomical time algorithmic solution can exist for any (exponentially) hard problem. However, there are mechanisms/techniques which when used in a solution of a hard problem, though divest the solution of its step-by-step or algorithmic characteristic, yet may make it a polynomial time solution. **Use of appropriate knowledge of the problem domain has been found useful in techniques that when used, solve hard problems in polynomial time**. Definition 3 declares the scope of (or the subject-matter) **AI as the study of techniques that exploit appropriate knowledge to solve hard problems in polynomial time.** The role of appropriate knowledge in reducing time complexity of a solution cannot be overemphasized. **The following simple example supports this claim abundantly:** Ms X is to meet Ms Y at her residence. Initially, let us assume that Ms X knows only that Ms Y lives in Delhi and knows nothing else about Ms Y's residence. A step-by-step or algorithmic solution to the problem may be to search the residential places, one by one, in some order, in Delhi and to stop when Ms. Y's place is located. The complexity of the algorithm, on the average, is undoubtedly very large. However, if X further knows that Y lives in some particular colony say Hauz Khas in Delhi, then search is substantially reduced by searching residential places only within Hauz Khas.

Further, if Ms X also knows the house number in Hauz Khas, then there is hardly any search required and X can *directly* reach Y's residence. Next, consider just opposite situation so far as availability of knowledge is concerned. Let us X even do not know that Y lives in Delhi. We can easily guess the plight of X when she, if follows a step-by-step method, is required to search, possibly all over the world, for the residence of Y.

The importance of (relevant) knowledge in solving difficult problems was recognised by the pioneers in the very early stages in the development of A.I. As we shall find subsequently, **major portion of A.I. is constituted of discussion of various issues about knowledge:** methods for *acquisition* of knowledge, for *representation* of knowledge, for *organisation* of knowledge, for *manipulation* of knowledge, for *maintenance* of knowledge and for *restricting search* of the problem domain by exploiting the knowledge of the domain.

1.6 DEFINITION BY BARR AND FEIGENBAUM

Next, we come to another definition of A.I. which involves *human intelligence* – a phenomenon only partially understood yet. Rather, computers and some A.I. techniques are being used in helping the psychologists in establishing their theories about intelligence and other mental processes. But this definition provides another angle to look at A.I. as the study of attempts at incorporating *intelligence*, whatever we understand of it yet, in machine. This definition, in a way, would also justify the inclusion of the word '*intelligence*' in the name '*Artificial Intelligence*' for the subject-matter of our study. **The definition, by Barr and Feigenbaum in 'The Handbook of Artificial Intelligence' [6], is as given below.**

Definition 4: Artificial Intelligence is the part of computer science concerned with designing intelligent computer systems, i.e., systems that exhibit the characteristics we associate with intelligence in human behaviour.

Discussion/Comments 2. Definition 4: *What is intelligence or intelligent behaviour in humans?* In order to have good grasp on the intent of this definition of A.I., *we attempt to enumerate some known characteristics of Intelligence*. There must be some basic mechanisms behind intelligent behaviour and some important attributes/characterises of intelligence which have defined human recognition or understanding, because of which we are not able to describe the phenomenon of intelligence in its totality. Capturing the total essence of the phenomenon of intelligence in humans through a definition is almost impossible, as is noted by one of the leaders of A.I viz. **Patrick Winston [7]** of Massachusetts Institute of Technology (MIT), when he states **"defining intelligence usually takes a semester-long struggle, and even after that I am not sure we ever get a definition really nailed down"**. However, there are some characteristics of intelligence which are readily acceptable, some others acceptable after some thinking and still others that may be controversial. We enumerate the characteristics as considered by some A.I. writers and contributors and others. Enumeration of these characteristics here is essential because as A.I. technologists, we would study various techniques that help us in incorporating these characteristics, through computer programs, into machines, which we attempt to make intelligent according to Definition 4 of Artificial Intelligence. We give below the attributes verbatim from the respective sources.

Douglous R. Holstadter in his book: 'Gödel Escher, Bach: An Eternal Golden Braid' [8], which won him Pulitzer Prize and was a best-seller mentions on Page 26 of the book, the following as essential abilities for intelligence:

- to respond to situations very flexibly;
- to take advantage of fortuitous circumstances;
- to make sense out of ambiguous or contradictory messages; to recognize the relative importance of different elements of situation;
- to find similarities between situations despite differences which may separate them;
- to draw distinctions between situations despite similarities which may link them;
- to synthesize new concepts by taking old concepts and putting them together in new ways;
- to come up with ideas which are novel.

Fisher and Firschein in their book 'Intelligence: The Eye, the Brain and the Computer' [9] on Page 4 state that they expect an intelligent agent to be able to:

- Have mental attitudes (beliefs, desires and intentions)
- Learn (ability to acquire new knowledge)
- Solve problems, including the ability to break complex problems into simpler parts.
- Understand, including the ability to make sense out of ambiguous or contradictory information.
- Plan and predict the consequence of contemplated actions, including the ability to compare and evaluate alternatives.
- Know the limits of its (own) knowledge and abilities.
- Draw distinctions between situations despite similarities.
- Be original, synthesize new concepts and ideas, and acquire and employ analogies.
- Generalize (find a common underlying pattern in superficially distinct situations)
- Perceive and model the external world
- Understand and use language and related symbolic tools.

They further state that there are a number of human attributes that are related to the concept of intelligence, but are normally considered distinct from it:

- Awareness (consciousness)
- Aesthetic appreciation (art, music)
- Emotion (anger, sorrow, pain, pleasure, love, hate)

- Sensory acuteness
- Muscular coordination (motor skills)

Next, we discuss 'intelligence' from more fundamental level. The ideas explained below are based on the *Information Transfer Model* of scientific phenomena due to **Norbert Wiener** (1894-1964). **Norbert Wiener,** an intellectual prodigy and author of the famous book entitled *Cybernetics* [14], suggested the *Transfer of Information* model to be a better model than the prevailing model based on *Transfer of Energy* for explanation of a number of scientific phenomena. Through the Wiener's theory, a new discipline was born, also, called *Cybernetics*

However, our discussion is mainly based on ideas explained in the book 'Beyond Information' by Tom Stonier [10]: According to the ideas explained in Stonier, there are four **fundamental properties of the universe viz. energy, matter, information and evolution (or change).** The cardinality of information in the universal scheme of things can be judged from the following argument: All the entities from down to nucleons to the whole of the universe, each is known to us as *an organised system* of simpler objects, e.g., fundamental particles organise into nucleolus, nucleolus organise to form atomic nuclei, which alongwith electrons and protons organise into atoms and so on. Molecules, polymers, membranes, organs, living beings, societies, planets, planetary systems, galaxies … and finally the whole universe, each is known as an organised system of some simpler objects. An organisation builds upon pre-existing organisations. **Thus an organised system is recursively obtained (or defined) as an interdependent assembly of elements and/or organised systems. And it is 'information'** what is exchanged between components of an organised system to effect their interdependence and *to maintain the integrity of the system as long as the system survives against the fourth fundamental property of the universe, i.e., evolution or change*. Gravitational pull, now an established entity, is just an information processing activity. **Thus 'information' is no more or no less an abstract concept than 'energy' or 'matter'. What mass is to matter and the heat is to energy, so is organisation to information**. Each of the former is a visible and measurable form of the corresponding latter. More the mass, more the matter in a system; more the heat, more the capacity to do work, i.e., energy in the system; similarly higher *the degree* (or more the complexity) *of the organization* (in terms of underlying organizations of the components and their components and so on, and in terms of the number and levels of interactions and relations between components at a particular level) higher is the *information content* of the system.

The relation between information and organisation and the characteristic difference between the two is exactly what **is the relation and characteristic difference between a number and a numeral.** A number is an *abstract* concept, wheras a numeral is its *physical manifestation or representation*. A number may have many representations and even may use many mediums for representations or manifestations. In the form **of, writing on the paper**, as patterns of ink dots on a piece of paper, the same number may be represented as 7 in decimal, 111 in binary, and even 4 + 2 + 1 again in decimal. In computer's memory, the same number is represented with the help of electronic components, a different medium, and not as shapes composed of ink-dots. In human brain the same number is represented, possibly, as some neural net.

Summarising, a *number* is a concept which needs a medium for its manifestation or physical representation for the purpose of conveying, or transformation. This representation is called a *numeral*. But it should be clear that when we say that '*I need two books*', the word 'two' is not just the sequence of three letters viz 't', 'w' and 'o' i.e., the representation, which is intended to be conveyed but just it is the *abstract* number which is intended to be conveyed. Because of the tangibility or perceptual 'visibility' of the representation, we always use the representation for various purposes like 'applying some operations' or for conveying, but it is not the representations, but the instances of the idea or concept (of number) which are intended to be transformed or conveyed.

Similarly, information is a concept and an organisation is its representation, i.e., physical manifestation. For the purpose of applying operations (like refining information, adding information etc) or for conveying information we use organisation (as patterns of ink dots on paper or as neural net in brain etc). Then, we manipulate the organisation or representation for applying operations on information (operations again are abstract, whereas manipulations are their physical realizations). Also, we communicate the organization for conveying information (communication is physical realisation of conveying). As in the case of number, information's representation may be through various organisations on various type of media such as patterns of ink dots on paper, neural nets in brain, or on flip-flops in electronic memory. For example, the information content of the organisation in the form of pattern of inkdots in the sentence 'Heat is a form of energy' is stored in the brain as an organization in the form of a Neural Network etc.

Remark 1: We have already mentioned that an atom is an organsied system and so are organ's in the human body and so are the galaxies in the universe. Also every organized system contains information. Hence, as we say 'God gave the numbers' so we can say 'God created information' **and information is not just a product of human mental activities.**

Remark 2: Information organises not only matter and energy but itself as well. Evolution leads to discontinuities, i.e., to something which is *qualitatively different* from the earlier existing entities. And intelligence is the phenomenon which has evolved out of information but which is qualitatively different from information.

Remark 3: Intelligence, being an outcome of evolution from information over a period spanning back almost upto the Big Bang, **must be a spectrum of phenomena and can not be an all or nothing affair.** Further, intelligence can not be a single-dimensional phenomenon. The veracity of this claim can be judged by analogy with evolution of matter and energy into myriad forms differing from each other in almost innumerable ways.

However, in order to draw a sort of fuzzy boundary between intelligent organisations or systems and the other systems, let us consider the case of living matter. Matter evolved from subatomic particles to atoms, molecules and so in potentially infinite number of different material objects. Out of these materials, there is a large number of types of objects (*for example, human beings*) for which we can say with surety that these are living matter and again for a large number of types of material objects (for example soil), we can say with surety that these are not living matters. Of course, there may still be large number of objects which may not be distinctly characterised as either. How we decide living or non-living is based on a finite collection of attributes of matter and degree of each such attribute.

In the similar manner, we consider a finite set of attributes and degrees for each attribute for organizations, i.e., information processing systems, which allow us to categorise systems as intelligent or otherwise in such a way that the systems which are generally considered as intelligent are categorised as intelligent and further whatever systems are generally considered as non-intelligent are categorized as non-intelligent. As evolution has taken over billions of years, hence divergence among information processing systems intelligence-wise must be potentially infinite. Thus any categorization based on only finite number of attributes would always be incomplete and leave large number of cases 'uncategorisable'. **To begin with, we start with a working definition of intelligence and then later expand on it:**

Intelligence is a property of advanced information processing systems, which not only engage in information processing, but are able to analyse their dynamically changing environment and to respond to it in such a way that:

i) survivability of the system is enhanced
ii) its reproducibility is enhanced (reproducibility is sort of self propagation through another system)
iii) if the system is goal-oriented, then achievability of goal is enhanced.

In stead of attempting to categorize most of the information processing systems as either intelligent or non-intelligent, if we are interested in their relative merit as intelligent systems, then the following principle of intelligence may be useful. **The principle quoted in Stonier [10] states: The intelligence exhibited by a system may, at least in theory, be measured as a ratio, or quotient, of the ability of a system to control its environment, versus the tendency of the system to be controlled by the environment.**

The above principle fits best, at least, in the limiting cases: At one extreme is a cube of sugar dissolving in a cup of tea. Although highly organised, the cube is totally controlled by environmental elements and hence, according to the above principle, it has zero intelligence. This is exactly what we also feel. On the other extreme is technologically advanced human society which can divert the waters of rivers to irrigate plains to provide an assured supply of food to its population. Thus intelligence measure of a technologically advanced society as a whole is, according to the above principle, quite high. This conclusion of the above principle is in consonance with what we also feel.

Below we include some more attributes and/or definitions of intelligence by leading computer scientists and A.I. researchers. The purpose is to be aware of as many facts as possible of yet-to-be completely understood phenomena of intelligence. Only then, it may be possible to design and develop really intelligent programs to solve those hard problems which are so far not amenable to computer solutions. Also, in this process, we are providing a list of attributes, against which an A.I. engineer can test their products for the quality of their product as intelligent one.

Hofstadter [8] on Page 37 says: It is an inherent property of intelligence that it can jump out of the task which it is performing and survey what it has done. **Self-evaluation and self-criticism are part of intelligent behaviour.**

Fishler and Firschein [9] on Page 4 state: Intelligence involves learning capability and goal-oriented behaviour. Additional attributes of intelligence include reasoning, common-sense, planning, perception, creativity, memory retention & recall.

Shanks [11] on Page 49 observes: The simplest and perhaps safest definition of intelligence is the ability to react to something new in a non-programmed way. The ability to be surprised or to think for oneself is really what we mean by intelligence.

In order to explain the concept of A.I. through 'Definition 4', we discussed the concept of intelligence itself as a phenomenon. Next, we quote another definition of A.I. again based on the concept of intelligence and given but from engineering point of view by another pioneer in the field, viz Shalkoff, a Professor of Electrical Engineering.

1.7 DEFINITION BY SHALKOFF

Definition 5: Shalkoff [13] says: 'Perhaps broadest definition is that AI is a field of study that seeks to explain and emulate intelligent behaviour in terms of computational processes'.

Comments 1, Definition 5: According to the above definition, AI is partly *scientific* in nature because it seeks to '*explain*' the phenomena of intelligence, and partly ***engineering*** because it seeks to '*emulate*' intelligent behaviour through computational processes, i.e., by generating representations (of knowledge) and development of programs that automatically (autonomously) solve problems, so far solved by only intelligent humans beings.

In view of the fact that A.I. is partly an engineering discipline according to the above definition, let us recall what is meant by the concept *engineering.*

Engineering may be thought of as the application of science and mathematics by which properties of matter and sources of energy in nature are made useful (*meeting some requirements and according to some specifications)* to man in structures, machines, products, systems and processes etc.

Again, in the light of the definition of **Engineering** given above, a part of the definition by Shalkoff may be paraphrased as '*…through application of A.I., products are obtained that exhibit intelligent behaviour….*' This paraphrased part of the definition by Shalkoff raises another issue: *How to judge/evaluate whether a product obtained through an application of A.I., is actually intelligent.*

The issue of testing an A.I. product as intelligent product was considered by the pioneers themselves including Alan Turing, the most well known name among the pioneers. In honour of Turing, the most prestigious award for contributions to the field of computer science, has been instituted and is given annually.

Turing suggested a test, which is well known as **Turing Test,** for testing whether a product has intelligence. An outline of the Turing test is given below.

For the purpose of the test, there are three rooms. In one of the rooms is a computer system claimed to have imbedded intelligence. In the other two rooms, two persons are sitting, one in each room. The role of one of the persons, let us call **A,** is to put questions to the computer and to the other person to be called **B**, without knowing to whom a particular question is being directed, and, of course, with the specific purpose of identifying the computer. On the other hand, the computer would answer in such a way that its identity is not revealed to **A.**

The communication among the three is only through computer terminals so that identity of the computer or the person **B** can be known only on the basis of quality of responses as intelligent or otherwise, and not just on the basis of other human or machine characteristics. If **A** is not able to know the identity of the computer, then computer is intelligent. More appropriately, if the computer is able to conceal its identity from **A,** then the computer is intelligent**.**

We may note here that, in order to be called intelligent, the computer should be clever enough not to give answer too quickly, at least not within a fraction of a second, even if it can, say, to a question involving finding of the product of two numbers each of more than 20 digits.

Objections to Turing Test: There have been a number of objections to the Turing test as a test of intelligence of a machine. One of the most well known objections is called **Chinese Room Test** proposed by John Searle. The essence of the Chinese Room Test, that we are going to explain below, is that convincing successfully by a system, say **A** , of possessing qualities of another system, say **B**, does not imply that the system **A** actually possesses the qualities of **B**. For example, the capability of convincing others by a male human of being a woman, does not give the male the quality of bearing a child like a woman.

The scenario for the **Chinese Room Test** consists of a single room with two windows. In the room a scholar on Shakespeare, knowing English, but not knowing Chinese, is sitting with a sort of encyclopedia on Shakespeare. The encyclopedia is printed in such a way that for each pair of facing pages, one page is written in Chinese characters and the other page is translation in English of the contents of the facing page in Chinese. Through one of the windows questions on Shakespeare's literature in Chinese characters are sent to the person sitting inside. The person looks through the encyclopedia and on finding in the encyclopedia the exact copy of the sequence of characters sent in, reads its translation in English, thinks of its answer and writes the answer in English for his/her own understanding, finds the corresponding sequence of Chinese characters in the encyclopedia, and sends the sequence of Chinese characters through the other window. Now, Searle says that, though the scholar successfully behaves as if s/he knows Chinese, but, as per assumption it is not so. Just from the fact that a system is able to simulate a quality, it can not be inferred that the system possesses the quality.

1.8 SUMMARY

This is an introductory unit to the course. The unit gives a bird's eye view of the whole of the course of *Artificial Intelligence*. The approach, in the unit, is to start with a definition by some pioneer in A.I. In the process of discussion of the definition, a number of relevant new concepts are gradually built up and discussed.

In **Section 0.3,** we discuss definition of A.I., as given by Eliane Rich **. It states: Artificial Intelligence is the study of how to make computers do things, at which, at the moment, people are better**.

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In this context, it was discussed that human beings are still better than computers in the problem areas, which require parallel processing and simultaneous availability of information.

According to the next definition of A.I., as given by Buchamin & Shortliffe:
AI is the branch of computer Science that deals with *symbolic* rather than numeric processing and *non-algorithmic* methods including the *rules of thumb or heuristics* in stead of *algorithms* as *techniques* for solving problems.

In Section 0.4, we discuss the differences (i) between number and symbol, (ii) between algorithmic and non-algorithmic methods of solving problems.

In the Section 0.5, another definition by Eliane Rich, as given below, is discussed:
Artificial Intelligence is the study of techniques for solving exponentially hard problems in polynomial time exploiting knowledge about the problem domain.

In context of this definition, we discuss the difference between 'exponentially hard problems' versus 'polynomial time' problem.

In section 0.6, we discuss the following definition of A.I. by Barr & Feigenbaum:
Artificial Intelligence is the part of computer science concerned with designing

intelligent computer systems, i.e., systems that exhibit the characteristics we associate with intelligence in human behaviour.

In context of this definition, we discuss various characteristics of human intelligence. In the process, we discuss, relation between information and organisation and relation between information and intelligence.

Finally, in Section 0.7, we discuss a definition of A.I by Shalkoff, an engineer. According to this definition, A.I. is partly an engineering and partly a scientific discipline. As an engineering discipline A.I. is the study of designing and developing intelligent machines. In context of testing whether a machine is intelligent, we discuss Turing test and its criticism.

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