INTELLIGENT SYSTEMS, MODELLING, SIMULATIONS AND THE APPLICATIONS

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ABSTRACT

The need for Intelligent Systems (ISs) in the world today cannot be overemphasized. An intelligent system is a system that learns how to act in order to reach its main objectives. Its action usually gears towards maximizing the probability of success and minimizing the probability of failure. Modeling an intelligent system usually involves studying a natural system which it intends to mimic and designing the model based on related parameters. This report presents a general overview of intelligent systems, a simple block diagram model of an intelligent system, a flow of its internal processes, the simulation overview, and then some applications.

Keywords: Intelligent System (IS), Simulation, Learns, Mimic, Environment

INTRODUCTION

So many definitions of intelligent system (IS) exist, but a more general definition was given in (Walter, 2006). According to this report, IS can be defined thus:

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.

This definition however implies that: 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, it means 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 *IS* 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* (Walter, 2006).

THE NEED FOR INTELLIGENT SYSTEMS

In the world today, intelligent systems are very useful, and the need for them arises as a result of the following:

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Control Of Complex Systems

If the behavior of real systems could be exactly predicted for all time using the solution of currently available mathematical models, it would not be necessary to control. One could just set the machine to work using certain fixed parameters that have been determined by calculation and it would perform exactly as predicted. Unfortunately there are several reasons why this is not currently possible.

a. The mathematical models that are used may be approximate in the sense that they do not exactly reproduce the behavior of the system (Mihir, 2006).

b. There may be unknown external *disturbances,* such as a change in environmental conditions that affect the response of the system.

c. The exact initial conditions to determine the state of the system may not be accurately known.

d. The model may be too complicated for exact analytical solutions. Computer-generated numerical solutions may have small errors that are magnified over time.

e. Numerical solutions may be too slow to be of used in real time. This is usually the case if PDEs or a large number of ODEs are involved (Mihir, 2006).

Design Of Complex Systems

Even if the equations governing the subsystems are not exact, they generally take a long time to solve. It is thus difficult to vary many parameters for design purposes (Mihir, 2006). In order to avert all these, there is need to adopt a system which has some intelligence, hence the need for intelligent systems.

REVIEW OF INTELLIGENT SYSTEMS

Intelligent system is an area that attracts the attention of many researchers. Consequently a lot of work has been published by several researchers in this area. Some of these works are concisely reviewed here includes: A report on computational tools to model intelligent systems under the paradigms of computational semiotics (Jose et al.,1999).The modeling artifact used in this paper is the framework given by object networks and mathematical objects.

In a paper on the principles of actions of intelligent systems the author formulated the main working principles of intelligent systems which reflect the most fundamental aspects of simulated reasoning and learning when interacting with the environment(Gavrilov. 2007). The principles he formulated includes: a) the principle of associative recall, b) the principle of concentration and economy of resources, c) the principle of uncertainty, d) the principle of unity in fuzzy reasoning and certain other operations. According to the author, these suggested principles are fundamental in describing the operations (behavior) of intelligent systems. All the other principles and models that exist before this formulation and those that can be further formulated are more specific and particular, and can be considered a consequence of the principles of his formulation.

A book on the techniques and applications of intelligent systems that presented the applications of IS techniques to solve a range of problems in the areas of olfaction, Engineering, Telecommunication, Antenna, and Medical diagnosis/imaging (Evor et al., 2008).

THE INTERNAL PROCESSES OF INTELLIGENT SYSTEMS

Here the main parts of both artificial and natural intelligent systems are explained. They include the following:

OBJECTIVES

All Intelligent Systems have a built in **main *objective***. Many ISs can also learn how (or have written within their code the ability) to create and use **sub objectives**; lower level and/or temporary objectives. By reaching these sub objectives the intelligent system gets nearer its main objective

Ranking "Objectives" Of Intelligent Systems

In its functioning and/or problem solving endeavors, and IS often needs to be able to rank the importance of many objectives against its perception of its current situation. One way it can measure the relative importance of a given objective is by assigning a number between zero and one that can be generated with a formula such as:

$$I = w/86400 \qquad \ldots\ldots (1)$$

Where, **I** is the importance of an objective, **w** is the seconds per day that the IS is willing to spend reaching for the objective, **86400** is the total amount of seconds in a day.

While we could have expressed this formula in terms of minutes or hours, we chose seconds because they are a more fundamental measuring unit in science.

There is also need to emphasize that while this formula involves the time the IS is willing to spend to achieve an objective, there is no known relationship between this time and the *actual* time that will be used. It turns out that the actual time is most highly dependent upon environmental parameters.

"Main Objective" Of Intelligent Systems

In artificial ISs, for instance in robots, the main objective is determined by the writer of the IS`s software. In [3], Isaac Asimov suggested and tested a triad of main objectives which he called the *"The Three Laws of Robotics"*. They are:

a. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

b. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

c. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

In other cases of artificial ISs, their main objective can be *acting* to maximize approval and minimize disapproval from a person (Mihir, 2006).

Generating Sub Objectives

Sub objectives are a certain situation which the IS wants to reach. It looks for response rules which are applicable to the present situation and which permits it to reach the sub-objective situation.
Artificial and natural ISs can also create their own sub objectives. For instance, there are some artificial ISs whose sub objectives can be generated by the system's "body." They may *sense* "pain" when they run into an object, get "tired" when awake too long, or get "hungry"

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when they have not "eaten" for a time. (All these are usually represented by ranges of number values of particular *present situation* variables).

SENSES

An IS need to have some senses so as to enable it know what is happening within its environment. The following are some questions that will enable us know what an intelligent system needs to know about its environment: **How** do *communications* about the environment reach the *IS*? **How** are they transformed into information and **how good** is this information? **How does** the IS represent its *environment* internally and **how good** is this representation? **Does it really** correspond to the environment? **Is this** representation useful for reaching conclusions and predicting the future environment (Walter, 2006)? Information about its environment does not occur spontaneously within a *system*. Rather, it has a *frontier* that limits the system from its environment. *Communications* from the environment can only reach the system by crossing its *frontier* at a *part* of the system that we call a ***sense*** **organ**. A sense organ is usually able to receive only a certain kind of *stimulus,* and thus only certain kinds of communication from the environment. For all *intelligent systems* (IS), the number of different types of sense organs they possess is not infinite: their number is severely limited. This also limits the type of communication an intelligent system can possibly receive and thus this limits the information, and thus the knowledge that the *system* can have about its *environment*.

CONCEPTS

A *concept* is the basic element of thought. It is a physical, material storage of *information* (in neurons or electronics) (Walter, 2006).

An *IS* creates concepts by the processing of what its *senses* tell it about its *environment*. Study has shown that all ISs, including humans, perceive their environment as: things, relationships between things and parts of things, movement of things, changes in things, and changes of relationship between things. In another form, we can say they perceive (spatial and temporal) ***structures*** and ***transformations***. The structures include objects and their relationships.

The sense organ is the first step in the process of obtaining this *information*. Later, when the *brain* receives this *sense* information (as nerve impulses) it processes it in such a way that it notes spatial and temporal relationships between some of the impulses. In the case that this relationship is similar to previously received information, it assigns the previous *concept* to the data. In the other case, it creates and assigns a new concept. These are the most *elementary concepts*.

Later, the *brain* of an IS uses these elementary concepts to build up higher level concepts, also called composite concepts. The mental processes then make use of these elementary and composite concepts.
All the concepts in memory are interrelated; they form a web, a net.

Concepts have links to those higher level concepts of which they themselves are parts. A wheel is part of a car; the concept "wheel" has a link to the concept "car". The concept "car" in turn is part of the concept "vehicle", and has the corresponding link. Concepts also have links in the other direction, namely to their parts. Naturally parts can themselves have parts. (The concept "tree" has links to its parts, to the concepts "roots", "stem", "branches" and "leaves").

When the brain has to decompose a concept it can decompose it by using the links to parts. Here it would use all the parts in place of the concept, for instance in place of "fruit" it would use: kernels **and** flesh **and** skin **and** … or it could decompose by using **any** of the concepts in its link to more concrete concepts: For instance, the abstract concept "fruit" would be replaced by: apple **or** banana **or** orange or…

Note that **elementary concepts** have no links to concretes. They are already the most concrete information that the brain possesses. In place of links to parts, they have detailed information of the sensation or elementary action. *Concepts* are not something that exist in our *environment*, its *structures*, or its *transformations*. Instead, concepts are something that exists only in the brain of an IS.

Using Concepts to Understand Environment

An IS cannot say that its environment **is** such and such. It can only say that it can **view** signals from its environment and attempt to link, store, and **express** them as a series of concepts. Amazingly, this is true, both for artificial and natural ISs, and it is this understanding of the environment that, to a great degree, limits the amount of *intelligence* that a *system* can achieve.

It turns out that we can set up a way for an IS to test itself on its understanding of the environment.

It is good to note that every time an *IS* has an *experience* that shows it something new about its *environment*, its *brain* creates a new *concept* or expands the corresponding, already existing concept and when a concept contains more *information*, we say that it is a "better" concept. It is also true that we can use concepts to "know" about how "things" act in our environment, but **cannot** use concepts to actually "know" the "thing itself".

Present Situation

This is the *situation* in which the IS finds itself at present. The IS builds up a *present situation* from the elementary concepts described previously.

For instance, if you intend to walk across a street, you would first ask yourself a few appropriate questions such as: Is the path clear? Is a vehicle coming from the left? Is one coming from the right? Is there a traffic light? If so, what color is it? After you have answered these questions, this information can be coordinated and linked to build a conceptual model of the *situation* in which you find yourself. Only when you have built up this *present situation* can you cross the street safely.

Enhancing the Present Situation

The **artificial** *IS* uses all three present situations, the one composed of elementary concepts, that consisting of (total) concepts and that composed of (abstract) concepts, in selecting a *response* to be done. Also the human being selects the response to be done based on the present situation.

Verification of the Present Situation

To function at its best, an *IS* should have a consistent picture of its *environment*. As part of this, an *IS* should not blindly accept all the *information* it receives from other IS's, directly or indirectly. It should, instead, review all the incoming information, especially if this information is about important matters.

Having built up an accurate *present situation* is not a suitable end goal; rather it is just one step in the long process of finding an adequate *response rule* so that the IS can do the corresponding action.

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RESPONSE RULES

Response rules are possibly the most important *part* of an *IS*. They are the knowledge that permits an IS to respond to a *stimulus*, and thus, to *act* in a given way to a given *situation* (Walter, 2006).

In artificial ISs, response rules consist mainly of a situation statement and a response. There are often complementary features besides these two. For instance: the moment when the IS used the response rule for the last time; the *pleasure* or pain resulting from the application of the response rule; the positive or negative weight of the *concepts* in the situation statement.

Instincts are a particular subset of response rules that are present at the start of the existence of the IS. In humans they are present at birth and include such actions as holding on and sucking, both of which are responses that babies needed to stay alive, at least at some period of evolution. In artificial ISs, curiosity and other general response rules are sometimes seen as beneficial and are incorporated into the original programming of the system.

MENTAL METHODS

Mental methods are *response rules* whose action occurs only in the brain. They can be response rules for managing information, for instance those used when we imagine something. Also they can be very general response rules, including various levels of abstract response rules.
Learned activity, *concepts* and *response rules,* accumulate continuously over the life span of an *IS*. If we wanted to model this accumulation, we could let R be the amount of response rules existing at time t, k_1 be the average *learning* factor, k_2 be the average forgetting factor, and Dt be the interval of time since the start of the IS. The formula for this could then be represented as:

$$R_t = k_1 \times (Dt) - k_2 \times (Dt) \qquad (2)$$

The same is true for concepts. Naturally, this simple formula does not say anything about the usefulness of learned response rules. For that we would have to expand the formula, adding the usefulness of all response rules. But still, response rules that exist must have certain usefulness; otherwise the brain would have forgotten them or never learned them in the first place.

If the span of life is considerable, some response rules learned early in life may not be applicable anymore, due to a change in *environmental* conditions.

Selection of Responses

So far, we have explored an *IS* that has created *concepts*; then, with these, created a representation for the *present situation*; created and stored a variety of *response rules*; and now, finally has to select the *response* to be done. To select one response rather than another, the IS has to have some reason or method for selecting it from the stored response rules.

Selection Mechanism of An Artificial IS

In artificial ISs, the *brain* first attempts to make a list of the response rules that are applicable to the present concrete *situation*. ("Applicable" here means that the response rule has some *concepts* in its situation part that also occur in the *present situation*.) If it does not find any applicable response rules, it expresses the present situation, where possible, with total concepts (Each concept has a branch where the program has stored the total concepts, of which the present concept is a part). Then again it looks for applicable response rules. If that also fails, now it expresses the present situation, where possible, with abstract concepts.

(Each concept also has a branch where the program has stored all abstract concepts, of which the present concept is a concrete example).In this list the rules are associated with a value that indicates how useful the rule was in the past and how much coincidence there is between the present situation and the initial situation of the response rule.

Once it has finished building the list of applicable response rules, the IS selects a rule. We would think that it picks the rule with the highest value. But that is not the case .Since its value is increased because it had success, the rule has a better chance to be selected the next time.

ACTIONS

From the perspective of an *IS* (intelligent system), an *action* is the final *part* of a long process. This process starts with the IS obtaining *information* from its *senses*, continues with the creation of a *present situation*, continues with the selection of an adequate *response rule*, and finally comes around full circle as an action is performed as the *response* part of that selected response rule. An *action* changes the *present situation* into a future *situation*. A useful and accurate way to represent this is with a mathematical representation. The following is one example of what a formula for this relationship might look like:

$$A(S_t) = S_{(t+1)} \qquad \text{3}$$

Where A is an action, t is time and S is a situation.

Classification of Actions

Action can be classified as cooperation, as neutral, or as an attack. A cooperation is an action by an IS, helping another to reach its *objectives* (this normally is mutual). An attack is an action by one IS which hinders another in its attempts to reach its objectives. Also this is normally mutual: it results in reciprocal attacks, or a fight. A neutral action is one that does not affect any other ISs or helps them as much as it hinders them.

Long Term Effects of Actions

It is also interesting to observe that the effect of most actions diminish with time (sometimes with much time): After a certain amount of time, the *environment* will be just as if this particular action had never occurred.

Reinforcement

Feedback, reinforcement, is a very important mechanism that increases the value of some *response rules* and decreases the value of others. Feedback is provided to the *brain* from two very different sources:

1. by the *environment*, through effects on the body,
2. by a "teacher's" intentional communication.

Through this feedback, response rules are increased or decreased in value, as needed.

Memory and Forgetting

All *ISs* have a memory where the *brain* stores *response rules* and *concepts*. In natural ISs, the brain stores response rules and concepts in neural fields. In artificial ISs, it stores response rules and concepts as numbers in computer memory.

All *Iss* Have To Forget

The new *information*, which is continually accumulating, eventually gets too big for any natural or artificial IS to hold. Thus, to make space for new, more important information, it has to forget information proven unimportant or which it has not used for a long time. Often,

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the brain retains only *abstracted* or *composite* information and forgets the details of the *concrete* information.

Sleeping (Reviewing Experiences)

We can observe the need for humans to sleep after a day that has been full of new *experiences*. The *mind* is confused and usually does not clearly see the relationships between all that has happened. After a night's sleep, the *situation* becomes much clearer.

Artificial *ISs*, also need to sleep. Some of its review processes take a considerable amount of time. As the external *activities* of an IS would be hindered if long internal processing continuously interrupted them, artificial ISs usually do substantive processing activities when no demands exist for external activity.

PATTERNS

In a most general sense we can say that the activity of a brain, biological or artificial, is the **discovery** of *patterns*, the **storing** of patterns and the **use** of patterns (Walter, 2011). The *mind* has an innate capability to recognize *patterns*. This capability is basic within the process that creates higher level *concepts*. In that process, the *IS* receives *information* from its various *senses*. It then searches within this information until it perceives a set, or pattern, that it already knows, between parts of the information. These parts it then replaces by the concept that expresses the pattern. If, instead of a known pattern, a new pattern is discovered, the mind of the IS learns this new pattern and creates a new concept.

Learning, in the artificial brain, is basically a discovery of patterns. It is a finding of patterns **within** the input data (senses) and also **within** the output data (acting). These patterns are newly created *concepts*. Furthermore learning is a finding of patterns **between** the input and the output. These are newly created *response rules*. Rules are similar to "productions" used in expert systems. They also have an input and show the corresponding output. The robot brain uses response rules and patterns when it decides what to do in a given situation. In the biological brain, dendrite connections are the **pattern**. The brain continuously tries to create further useful dendrite connections and inactivates those connections found useless. Making an axon connection to another neuron nearer the output of the brain is somewhat like making a response rule.

ANALYSIS AND METHODOLOGY

The modeling of an intelligent system basically depends on the action desired and the complexity of the system in mind. Artificial intelligent systems for instance usually require modeling the natural system which is meant to be mimicked. But generally intelligent systems have some behaviors or characteristics which must be considered during modeling, in other words, they have a common internal process.

Block Diagram of A Simple Intelligent System

A simple block diagram of an intelligent system is as shown in Figure 1

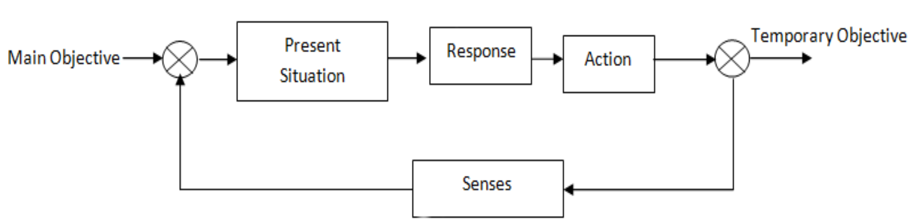

Figure1. A Simple block diagram of an intelligent system.

The figure shows that an intelligent system has a temporary *objective*, which it derives from its main objective. Its main aim is to ensure that the temporary objective matches its main objective. It achieves this through the other blocks. So while the main objective is taken to be the input, the temporary objective (which is what it finally achieved at a point) is taken to be the output. 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*.

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*. The intelligent system continually records the present situation and the action that follows 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 a while, its memory is full and it forgets the least used concepts and response rules.

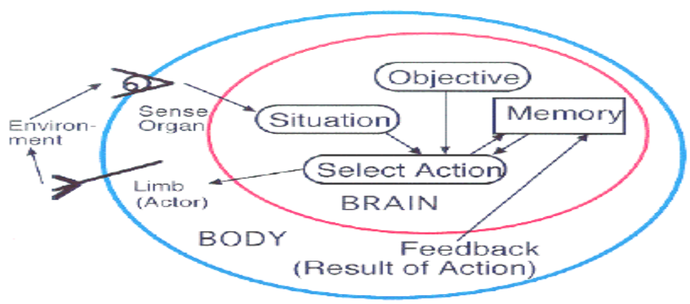

Figure 2. Overview of intelligent systems

The figure shows that an intelligent system comprises basically of two main components, the brain and body. It also shows the different processes that take place in each of the components and the details of the processes is as described earlier. The brain carries out all the decision processes while the body houses the brain and the other parts of the intelligent system. Sensing the environment starts from the body, after which the sensed data is sent to the brain for onward processing.

Algorithm of a Simple Intelligent System

Figure 3 shows a flowchart that summarizes the general internal operation of an intelligent system. It is worthy of note here to mention that an intelligent system is usually software - based. To model and develop a good intelligent system is to develop good software, and to develop good software there must be a good algorithm in place to guide the software developer. The flowchart depicts what happens from start through action and then to the time the system sleeps (time of inactivity).

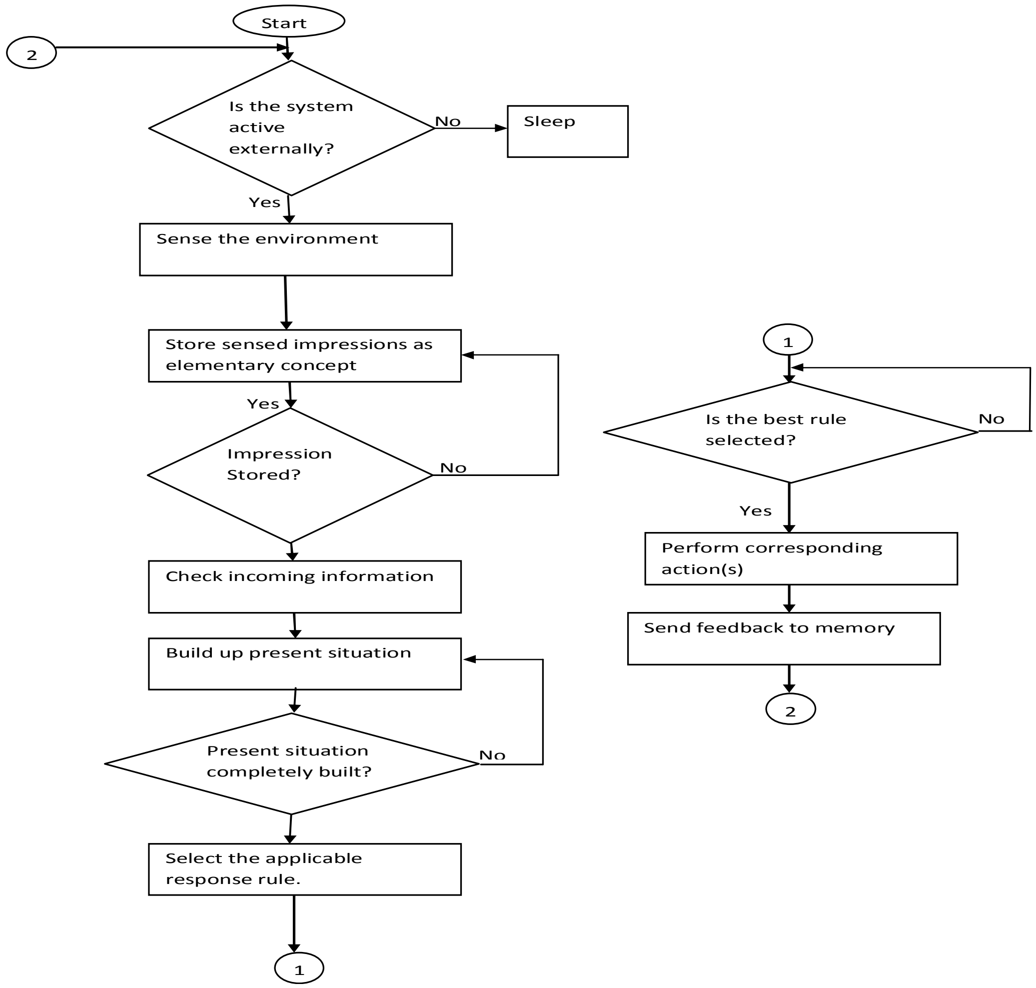

Figure 3. Flowchart of the internal processes of intelligent systems

Simulation of an Intelligent System

After the intelligent system has been developed, it is important to simulate it to ensure that it does exactly what it is designed to do. Simulating the system is all about varying some parameters to test the action that follows. Usually the temporary objective should near its main objective, reason being that an intelligent system tries to maximize the probability of success and minimize the probability of failure. So parameters should be varied to ensure that the input which is the main objective is achieved through a continuous comparison with the output (temporary objective).

By following the internal processes depicted in figure 3, and varying some key parameters, the developer checks if the system is achieving its main objectives. Through simulation also the system can be tested to know how responsive it is to a particular physical quantity, say temperature, pressure etc.

APPLICATION OF INTELLIGENT SYSTEMS

In recent years the need for improved monitoring and automated systems has necessitated the application of intelligent systems in various areas of life. Intelligent systems find wide application in the following areas:

Healthcare

Improvement in the health sectors today can be traced to the use of sophisticated intelligent systems in this sector. With the use of these intelligent systems the following are possible:

i. Reduction in missing patient's records
ii. Avoidance of poor handwriting conducted by certain physicians and nursing staff
iii. Avoidance of the use of non-standard abbreviations for medical terms,
iv. Avoidance of misplaced or lost patient charts
v. Avoidance of multiple versions of documents/forms
vi. Ability to chart a record right after an event
vii. Convenience in looking up patient records for decision support,
viii. High efficiency in general patient care services.

Business

IS also finds applications in several areas of business. For instance, business intelligent systems contribute to improvement and transparency of information flow and knowledge management. They also enable organizations to:

a. follow profitability of their products sold;
b. analyse expenditures;
c. monitor corporate environments; and
d. discover business anomalies and frauds.

Tutoring Systems

Intelligent systems can also be used in multimedia intelligent tutoring system (ITS) for simulation modeling. Multimedia systems are now de facto standard on personal computers and increasing number of intelligent tutoring systems incorporate multimedia systems to enhance interaction with students. An intelligent tutoring system can provide a graphical environment in which the student can practice conceptual model development and interact direct with different simulation modeling.

Robotics

Here intelligent systems are designed as robots. These robots can be used to perform different functions, ranging from domestic to industrial functions. The use of robots helps to reduce human workload and improves efficiency.

Vehicles

Recently, intelligent systems are embedded in vehicles to help automate and control some operations.

Satellite communication systems

In satellite communications, the docking and refueling can be achieved using intelligent systems.

Autopilot systems

Here intelligent systems can be embedded in aircrafts and rockets to perform the functions of a pilot.

CONCLUSION

In this paper, it was made clear that an intelligent system is a system that has its main objectives as well as senses and actuators. It is a system that learns how to act in order to

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reach its main objectives. A system is more intelligent if it reaches its main objectives faster and easier.

Generally in modeling intelligent systems its internal processes has to be put into consideration so as to be able to realize a system that is considerably intelligent. So considering the internal processes described in this paper, it can be seen that in order for an intelligent system to achieve its main objectives, it first senses the environment, saves the sensed information, creates present situation, selects adequate response rule, responds, takes action and then saves the action taken in the memory as a new response rule. This summarizes what happens internally in all intelligent systems. So using this to develop the program, the developer now follows these steps during simulation to ensure that the IS achieves its main objective.

Intelligent systems find wide applications in areas such as robotic, healthcare, tutoring systems, games etc.

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