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An Overview of Abstract and Physical Characteristics of "Artificial Life Systems"

Ashwani Kumar

[*] Department, Institute Name Assistant Professor, Department of Computer Science & Engineering, F.E.T. Agra College, Agra, INDIA

***Abstract*- Artificial Life Systems (ALife Systems):** A lot of efforts have been made during the recent decades to investigate and understand the key and controversial issues in natural phenomena / world through computer simulation. Artificial Life is one such an area that is growing very rapidly today. The main idea behind the rapid development of Artificial Life Systems is to develop a system that possesses the capabilities not to just replace (as a substitute) the human beings but also lead in the various aspects of life, such as survival, reproduction, selection, intelligence, expertization, civilization, feeling, creativity, forecasting, sacrificing, stability, curicity, and many more.

Life is abstract in nature. It is just an ordered and unordered set of events, opportunities, and experiences, some of them are synchronous and certain while on the other hand rest of them are asynchronous and uncertain. In the life, the effective decision making (i.e. taking right decision at right time) plays a vital role. For example: When there is a situation to take a strict decision we definitely go through Crisp Logic, on the other hand if there is a flexible situation then we may go through Fuzzy Logic.

Natural Life Systems are not completely (purely) based on the "Stored Program Concept" because there is no script (program) for the life of a human. But in spite of that every human tends to attempt to script his / her schedule to get the optimal results among the feasible situations. So definitely "Stored Program Concept" is a first benchmark between "Natural Life Systems" and "Artificial Life Systems".

Besides this the most important thing in this context is that we have to design a methodology through which an artificial life system could modify its response during the run time (life time), and of course it is the necessary and sufficient condition for an Artificial Life System to be dynamic in nature.

In this paper we not only described "What is ALife?", but also discussed its principal concerns, and also provide a flavors of the kind of the work that is being attempted to develop and understand the ALife Systems.

***Index Terms*-** About four key words or phrases in alphabetical order, separated by commas. Keywords are used to retrieve documents in an information system such as an online journal or a search engine. (Mention 4-5 keywords)

I. INTRODUCTION TO "A LIFE"

Before starting any discussion on Artificial Life in this paper, we are intended to be bound to start with a more basic question- "What is life?"

- State of a functional activity and continual change, before death (End of Life).
- Characterized by the capability to reproduce itself.
- Adapt to an environment in a quest for survival.
- Take Actions independent of exterior agents.
- Biology is the scientific study of Life on Earth based on Carbon-Chain Chemistry.
- Life is one such long process of getting tired.
- How to make robust and adaptable computer systems? (Computer Science)
- Life is how you take it.

"Artificial Life is a Life made by Human rather than Nature. i.e. the study of man made systems that exhibit behaviours (characteristics) of natural living systems."

"Artificial Life, or ALife is the study of non-organic organisms, beyond the creations of nature, that possess the essential properties of life as we understand it, and whose environment is artificially created in an alternative media, which very often is a logical device like the computer."

"Artificial Life studies the evolution of agents, or populations of computer-simulated life forms in artificial environments."

In particular we describe an attempts concerning three main characteristics of living beings:

- Reproduction
- Emergent Properties
- Evolution

In this paper our attempt is just to explore the concept of ALife and characteristics of Alife Systems. So our attempt is not to be exhaustive. The issues, which we will discuss later on in this paper, are still going on in the field.

II. REPRODUCTION IN NATURAL LIVINGS

- During sexual reproduction, crossover occurs.
- This recombination of chromosomes become the new individual.
- Hence genetic information is shared between the parents in order to create new offspring.
- During reproduction "errors" occur: mutation.

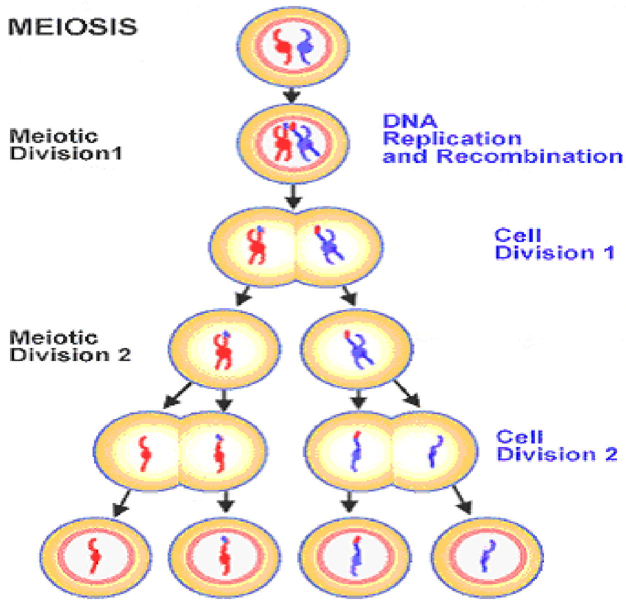


Figure (a): Reproduction

III. "ALIFE": SYNTHESIS APPORACH

Rather than being an analytical study of Natural Life, ALife is a synthesis approach to studying any form of Life.

We have:

- An artificially created environment (usually) within computers.
- A fairly universal set of rules and properties of life, derived from the one example we have of life - Natural life.

IV. MOTIVATION BEHIND "ALIFE"

A-Life could have been dubbed as yet-another-approach to studying intelligent life, had it not been for the Emergent properties in life that motivates scientists to explore the possibility of artificially creating life and expecting the unexpected.

An Emergent property is created when something becomes more than sum of its parts. For example, half a human is not capable of working without the other half, but together, capable of very complex behaviour (not a representative example).

V. "ALIFE": FEASIBLE DOMAINS

The ALife concept helps to:

- Study existing natural life forms by trying to simulate the generic rules they follow, the environmental parameters like entropy/chaos, and the seed, i.e. the initial set of elements on which the rules of life apply under the given environmental condition, in order to understand evolution in nature.
- Create new life within the digital world by creating new set of external parameters, seeds, and rules of evolution, and let life find a way.

VI. WEATHER "ALIFE" = "AI"??

Both seem to approach similar type of problems, but….

ALife	**Artificial Intelligence**
Concept: Late 1980s.	Concept: Late 1960s.
Grounded in Biology, Physics, Chemistry, & Mathematics.	Pursued primarily in Comp. Science, Engineering & Psychology.
Studies Intelligence as part of Life.	Itself Studies Intelligent behaviour in isolation.
Bottom-Up approach – study synthesis.	Top-Down approach – focus is on results.
Views life-as-it-could-be.	Views life-as-it-is.

Table (a): ALife vs AI

VII. "ALIFE": ROLE OF EMERGENCE

"Another process predominating ALife systems is that of 'Emergence', where phenomena at a certain level arise from interactions at lower levels."

In physical systems temperature and pressure are the examples of emergent phenomena. They occur in large ensembles of molecules and are due to interactions at molecular level. An individual molecule possesses neither temperature nor pressure, but when they interact at higher level then resulting an emergent phenomenon.

"ALife systems consist of a very large collection of simple, basic units whose interesting properties are those that emerge at certain higher levels."

We have some examples that will illustrate the importance of Emergence in ALife Systems:

- **John Von Neumann's model of "Cellular Automation":**

John Von Neumann is widely credited with the origination of the of "Stored Program Concept", that forms the basis of working of a vast majority of machines in todays era. But his contribution to the advancement in ALife studies is no less compelling, although relatively unknown.

"Can a machine reproduce itself?" This question was posed by John Von Neumann in the early 1950s and explored by him before his untimely death in 1957. Specifically he asked weather an artificial machine could create a copy of itself, which in turn could create more copies (in analogy to nature).

John Von Neumann wished to invitigate necessary logic for the reproduction. He was not interested, nor he did have the tools, in building a working machine at the bio-chemical or genetic level. Remember that at that time DNA had not yet been discovered as the genetic material in nature.

One such example is John Von Neumann's model of "Cellular Automation", where the basic units are the "Grid Cells" and the observed phenomena involve composite objects consisting of several cells. A machine in the Cellular Automata model is a collection of cells that can be regarded as operating in unison. For example if a square configuration of four black cells exists, that appears at each time step one cell to the right, then we say that square acts as a machine moving right.

John Von Neumann used this simple model to describe a universal constructing machine, which can read assembly instructions of any given machine, and construct that machine accordingly. These instructions are the collection of cells of various colors, as the new machine after being assembled – indeed any compound element on the grid is simply a collection of cells.

John Von Neumann's universal constructor can build any machine when given the appropriate assembly instructions. If these consist of instructions for building a universal constructor, then the machine can create a duplicate of itself; that is, it will reproduce. Should we want the offspring to reproduce as well, we must copy the assembly instructions and attach them to it. In this manner the John Von Neumann showed that a reproductive process is possible in Artificial Machines (ALife Systems).

One of the John Von Neumann's main conclusions was that the reproductive process uses the assembly instructions in two distinct manners:

1. As interpreted code. (During actual assembly).
2. As uninterrupted data. (Copying of assembly instructions to offspring).

During the following decade when the basic genetic mechanisms began to unfold, it became clear that nature had adopted the John Von Neumann's conclusions. The process by which assembly instructions (that is DNA) are used to create a working machine (that is, proteins), indeed makes dual use of information: As interpreted code and as uninterrupted data. The former is referred to in biology as "Translation" and later is referred to as "Transcription" in the terminology of computer science.

This description demonstrates the underlying approach of ALife. The field draws researchers from different disciplines such as computer science, physics, biology, chemistry, economics philosophy and so on. While biological research is essentially analytic, trying to break down the complex phenomena into their basic components, ALife is synthetic, attempting to construct phenomena from their elemental units. As such ALife complements traditional biological research by exploring new paths in the quest toward understanding the grand and ancient puzzle called "Life".

- **Craig Reynolds's work on the "Flocking behaviour of Birds":**

Another example is Craig Reynolds's work on the "Flocking behaviour of Birds". Reynolds wished to invitigate how flock of birds fly, without the central direction (that is a leader). He created a virtual bird with basic flight capability called a "boid". The computerized world was populated with a collection of boids, flying in accordance with the following three rules:

1. **Collision Avoidance:** Avoid collisions with nearby flock-mates.
2. **Velocity Matching:** Attempt to match velocity with nearby flock-mates.
3. **Flock Centering:** Attempt to stay close to nearby flock-mates.

Each boid comprises a basic unit that "sees" only its nearby flock-mates and "flies" according to three rules. These three rules served as sufficient basis for the emergence of the flocking behaviour. The boid flew as a cohesive group, and when the obstacles appeared in their way they spontaneously split into two subgroups without any central guidance, rejoining again after clearing the obstruction. The boid algorithm has been used to produce photo-realistic imagery of bat swarms for the feature motion picture Batman Returns and Cliffhanger.

Reynolds's model demonstrates the basic architecture of ALife Systems – A large number of elemental units relatively simple, and interacting with a small number of nearby neighbours, with no central controller. High-level emergent phenomena resulting from these low level interactions are observed. Although Reynolds's boids are artificial, the flocking behaviour is as real as that observed in nature. (This point was also noted for Von Neumann's reproductive process.)

- **"Foraging behaviour of Ants":**

One more example is the "Foraging behaviour of Ants". The optimal foraging policy has been learned from biological phenomenon of these socially adapting living creatures. Foraging Theory is based on the assumption that the animal search for and obtain nutrients in a way that maximizes their energy intake E per unit time T spent foraging. The maximization of such a function provides nutrients sources for the animal to survive and additional time for other important activities (e.g. fighting, fleeting, mating, reproducing, sleeping, or shelter building etc). Shelter-building and mate-finding activities are sometimes similar to foraging. Clearly, foraging is very different for different species. The foraging formulation is only meant to be a model that explains the optimal behaviour.

Ants have been living on the earth for more than 100 million years and can be found almost any where on the planet. It is estimated that there are 20000 different species of ants. For this reason, they have been called the earth's most successful species. Ants are social insects, which means they live in large colonies or groups. Some colony consist of million of ants. The eyes of ants are made up of many lenses enabling them to see movement very well. Their antennae are special organ of smell, touch, taste, and hearing. If you watch ants for some time, you will see that they really do communicate with each other, and very effectively too. They communicate by touching each other with their antennae. They also use chemicals called pheromones to leave scant trails for other ants to follow. Different ants have their own specialized activities for survival. So Emergence has came into existence since:

1. What you get when something is more than the sum of its parts.

2. Human thoughts rely on nearly all cells that make up the brain - single cells are incapable of thought - thought is the emergence property of these cells coming together and interacting to give complex results - motivation behind Cellular Automata, and Neural Networks.

3. Extreme example: Earth as a one living thing, consisting of whole of nature being in dynamic equilibrium, each part having bearing on the other.

VIII. ENTROPY OF ALIFE SYSTEMS

"Life is just all about fighting against entropy: as other systems lose information to surroundings, life not only keeps hold its information, but also increases the amount of information and corelating it to enhance the Knowledge Base"

"Second Law of Thermodynamics: When two systems are joined together, the entropy (or chaos) in the combined system is greater than the sum of the individual systems."

This roughly applies to all systems, including those that holds and exchange information.

IX. COMPLEXITY OF "ALIFE" SYSTEMS

"Life is a complex system: It is a dynamic system that can keep on changing and evolving over a great period of time without dying."

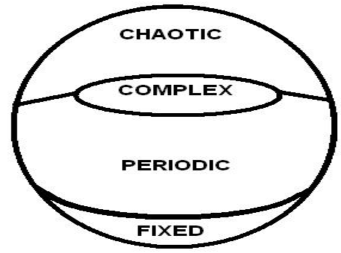
If the amount of information exchange in a system is varied from low to high, it gives "Fixed", "Periodic", and "Chaotic" systems in that order. Somewhere in between, a system exhibits "Complex" behaviour.

Accordingly, each unit (cell) in a system dies, freezes, pulsates, or behaves in a very complex manner.

	CHANGE	**EVOLUTION**	**DEATH**
FIXED	NO	NO	NO
PEROIDIC	YES	NO	NO
CHAOTIC	YES	YES	YES
COMPLEX	YES	YES	NO

Table (b): Complexity of ALife Systems

Figure (b): Various models of Life



X. "ALIFE": FUNDAMENTAL ALGORITHMS USED

- **NEURAL NETWORKS**
- **EVOLUTIONARY ALGORITHMS**
  1. Genetic programming
  2. Evolutionary programming
  3. Classifier Systems
  4. Lindenmeyer Systems
- **CELLULAR AUTOMATA**

XI. "ALIFE": CHAOS THEORY

Chaos theory is a field of study in mathematics, with applications in several disciplines including physics, engineering, economics, biology, and philosophy. Chaos theory studies the behaviour of dynamical systems that are highly sensitive to initial conditions, an effect which is popularly referred to as the butterfly effect. Small differences in initial conditions (such as those due to rounding errors in numerical computation) yield widely diverging outcomes for chaotic systems, rendering long-term prediction impossible in general. This happens even though these systems are deterministic, meaning that their future behaviour is fully determined by their initial conditions, with no random elements involved. In other words, the deterministic nature of these systems does not make them predictable. This behaviour is known as deterministic chaos, or simply chaos.

Chaos Theory explains apparent randomness - many apparently random events are not truly random - they are just iteration of simple rules on existing states (and possibly previous states) generating complex behaviour - they live on the edge of total chaos.

Chaotic behaviour can be observed in many natural systems, such as weather. Explanation of such behaviour may be sought through analysis of a chaotic mathematical model, or through analytical techniques such as recurrence plots and Poincaré maps.

Most natural processes are chaotic – Ex: sea, wind. Some man-made processes are chaotic – Ex. Financial market.

Lack of knowledge of all rules, inputs and seed prevents us from determining the exact state of such a system at a point, but knowledge of some of those dominant rules/inputs lead to possible prediction of general behaviour of the system. This lack of knowledge of all parameters leads us to conclude it to be random behaviour of the system.

In common usage, "chaos" means "a state of disorder". However, in chaos theory, the term is defined more precisely. Although there is no universally accepted mathematical definition of chaos, a commonly used definition says that, for a dynamical system to be classified as chaotic, it must have the following properties:

1. It must be sensitive to initial conditions.
2. It must be topologically mixing.
3. Its periodic orbits must be dense.

The requirement for sensitive dependence on initial conditions implies that there is a set of initial conditions of positive measure, which do not converge to a cycle of any length.

Sensitivity to initial conditions:

Sensitivity to initial conditions means that other points with significantly different future trajectories arbitrarily closely approximate each point in such a system. Thus, an arbitrarily small perturbation of the current trajectory may lead to significantly different future behaviour. However, it has been shown that the last two properties in the list above actually imply sensitivity to initial conditions and if attention is restricted to intervals, the second property implies the other two (an alternative, and in general weaker, definition of chaos uses only the first two properties in the above list). It is interesting that the most practically significant condition, that of sensitivity to initial conditions, is actually redundant in the definition, being implied by two (or for intervals, one) purely topological conditions, which are therefore of greater interest to mathematicians.

Sensitivity to initial conditions is popularly known as the "Butterfly Effect", so called because of the title of a paper given by Edward Lorenz in 1972 to the American Association for the Advancement of Science in Washington, D.C. entitled Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas? The flapping wing represents a small change in the initial condition of the system, which causes a chain of events leading to large-scale phenomena. Had the butterfly not flapped its wings, the trajectory of the system might have been vastly different.

A consequence of sensitivity to initial conditions is that if we start with only a finite amount of information about the system (as is usually the case in practice), then beyond a certain time the system will no longer be predictable. This is most familiar in the case of weather, which is generally predictable only about a week ahead.

Distinguishing Random Data from Chaotic Data:

It can be difficult to tell from data whether a physical or other observed process is random or chaotic, because in practice no time series consists of pure 'signal.' There will always be some form of corrupting noise, even if it is present as round-off or truncation error. Thus any real time series, even if mostly deterministic, will contain some amount of randomness.

All methods for distinguishing deterministic and stochastic processes rely on the fact that a deterministic system always evolves in the same way from a given starting point. Thus, given a time series to test for determinism, one can:

1. Pick a test state. Call this state as the 'Initial State'.
2. Search the time series for a similar or 'Nearby State'.
3. Compare their respective time evolutions.

Define the error as the difference between the time evolution of the 'test' state and the time evolution of the nearby state. A deterministic system will have an error that either remains small (stable, regular solution) or increases exponentially with time (chaos). A Stochastic System will have a randomly distributed error. Essentially all measures of determinism taken from time series rely upon finding the closest states to a given 'test' state. To define the state of a system one typically relies on phase space embedding methods. Typically one chooses an embedding dimension, and investigates the propagation of the error between two nearby states. If the error looks random, one increases the dimension. If you can increase the dimension to obtain a deterministic looking error, then you are done. Though it may sound simple it is not really. One complication is that as the dimension increases the search for a nearby state requires a lot more computation time and a lot of data (the amount of data required increases exponentially with embedding dimension) to find a suitably close candidate. If the embedding dimension (number of measures per state) is chosen too small (less than the 'true' value) deterministic data can appear to be random but in theory there is no problem choosing the dimension too large – the method will work.

Some important points in context to the Chaos Theory are as follows:

- Chaos Theory explains apparent randomness - many apparently random events are not truly random - they are just iteration of simple rules on existing states (and possibly previous states) generating complex behaviour - they live on the edge of total chaos.

- Most natural processes are chaotic - sea, wind. Some man-made processes are chaotic - Financial market.

- Lack of knowledge of all rules, inputs and seed prevents us from determining the exact state of such a system at a point, but knowledge of some of those dominant rules/inputs lead to possible prediction of general behaviour of the system.

- This lack of knowledge of all parameters leads us to conclude it to be random behaviour of the system.

XII. "ALIFE": STUDY & PHILOSOPHY

Study into ALife is conducted primarily at three levels, these are:

1. **Wetware –** Using bits from biology (e.g. RNA, DNA) to investigate evolution.
2. **Software –** Simulating biological systems.
3. **Hardware –** For instance, robotics.

And with Two distinct philosophies:

1. **Strong ALife –** life is not just restricted to a Carbon-based chemical process. Life can be created in silicon.
2. **Weak ALife –** computer simulations are just that, simulations and investigations of life.

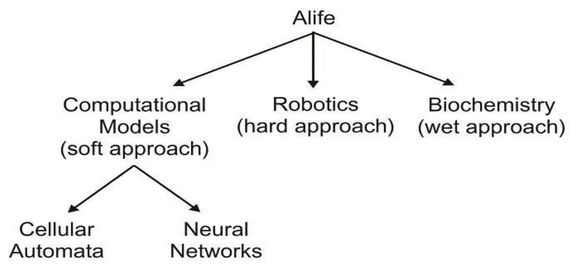


Figure (c): ALife Study

Traditionally: AI: A Top Down Approach
ALife: A Bottom Up Approach

XIII. "ALIFE": ROLE OF EVOLUTION

Evolution is central to ALife research. One of the major open problems facing scientists today is the "Origin of life ". How did the first self replicating organisms appear, an event considered to be a precursor to evolution, leading to the astounding variety of species found on the earth today.

Evolution is slowly but it surely produces populations in which individuals are suited to their environment.

- The characteristics / capabilities of individuals are defined by their chromosomes.
- Those individuals that are most fit (have the best characteristics / capabilities for their environment) are more likely to survive and reproduce.
- Since the chromosomes of the parents are combined in the offspring, combinations of fit characteristics / capabilities are passed on.
- With a small probability, mutations can also occur resulting in offspring with new characteristics / capabilities.
- **Biological Evolution and Social Evolution:**
  - Biological Evolution produces species by selecting among changes in the genome.
  - Social Evolution produces the knowledge / culture by operating on socially transmitted and modified units of information.

- **Rodney Brook's work on the development of ALife System via Emergence and Evolution:**

The underlying principal of ALife stand at the core of Rodney Brook's work. During the past decade, he has been involved in the construction of robots that can function in a (noisy) human environment. For example traveling in a building and collecting garbage. The robots possess "brains" comprised of a hierarchy of layers, each one performing more complex function. The first layer handles obstacle avoidance. The second is responsible for wandering behaviour. i.e. randomly circulating within in the environment (room, building). This layer does not contain itself with obstacle avoidance, science this issue is handled by the previous layer. Higher-level layers can subsume the role of lower levels by suppressing their outputs. However, lower level continue to function as the higher levels are added. This method dubbed the consumption architecture roughly resembles our own brain where primitive layers handle basic functions (for ex. Respiration) and high level layers handle more complex functions (for ex. Abstract thinking). Brook's scheme allows incremental construction of robots by adding to existing (operational layers). Thus enabling a sort of robotic evolution via emergence.

Brook's method for building the sophisticated robots demonstrates the ALife approach, which is fundamentally different than that of Traditional Artificial Intelligence (AI). AI attempts a Top Down Methodology, where complex behaviours (for ex. Chess playing) are identified and an attempt is made to build a system that presents all the details of this behaviour. ALife operates in bottom up manner, starting from the simple elemental units, gradually building it's way upwards through: Evolution, Emergence, and Development.

XIV. CONCLUSION

ALife thus is an innovative and interesting field of computer science. The above detailed description of activities is sufficient to show that the activities pursued under this label are aimed at replicating some of the very basic activities of living beings. The basic issues of ALife and AI pertain to the issues investigated. Whereas AI has traditionally concentrated on the complex functions of human beings, such as chess playing, text comprehension, medical diagnosis, and so on. ALife mainly concentrates on basic natural behaviours, emphasizing survivality in complex environments. According to Brook's, an examination of the evolution of life on earth reveals the most of the time was spent developing the basic intelligence. The elemental faculties evolved to enable mobility in a dynamic environment and sensing of the surroundings to a degree sufficient to achieve the necessary maintenance of life and reproduction.

The issues dealt with by AI appeared only very recently on the evolutionary scene and mostly in humans. This suggests that the problem-solving behaviour, language, expert knowledge, and reason are all rather simple once the essence of being and reacting is available. This idea is expressed in the title of one of the Brook's papers, 'Elephants Don't Play Chess', suggesting that these animals are nonetheless highly intelligent and able to survive and reproduce in a complex dynamic environment.

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AUTHORS

First Author – Ashwani Kumar (M.E. / CS&E)
Assistant Professor, Department of Computer Science & Engineering F.E.T. Agra College, Agra, (U.P.), India
Email: ashwani . sir @ gmail . com