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Epistemology of Nature inspired Artificial System

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***Abstract*—** The artificial intelligence is one of the most emerging area of research in the field of advance computing, which emphases a new direction of thought known as nature based computing or bio-inspired artificial system. The concept is based on the different organisms such as insect colonies, flock of birds or school of fish. This manuscript is presenting different algorithms which are useful to develop artificial systems by deploying different nature based ideas.

***Keywords*—** Evolutionary Algorithm, Behavioral System, Artificial Life, Swarm Intelligence, ACO, PSO

I. INTRODUCTION

To design human cognitive capabilities with computing machines or algorithm, the concept of artificial intelligence was introduced. The biological intelligence interestingly deployed to handle different types of problems in the field of data mining, optimization, complexity analysis and effective signal processing. Gradually it is found, that the artificial intelligence is more effective to control the problems which could not be handled by the human intelligence properly. The artificial intelligence has been applied to develop algorithms for the encapsulation with bio-medical devices, smart sensors, and autopilot mode, intelligent chess games, analysis of different hidden protein structures, identify the hidden pattern from high volume data sets. During the development of artificial intelligence some basic biological properties are not properly enclosed with the concept which helps natural organisms to face the external environment intelligently. The important properties of natural biological system is social interaction, social groups, self-healing, biological evolution, self learning, self autonomy and self organization, which helps the biological organism to be structured and control itself according to external environment. Many researchers try to decode the hidden engineering of intelligent systems. The identify the deep insight of biological intelligence various approaches has been developed such as artificial intelligence, cognitive computing, Artificial neural nets (ANN), swarm intelligence and behavior based instruments. Various hypothesis and artifacts are developed to understand the internal taxonomy of operational activities and performance characteristics of natural intelligence. The artificial intelligence is the approach to understand the activities of human brain properly and internals of cognitive capabilities required for reasoning. The cognition is a kind of process that is practiced by the human or animal to develop the consciousness by the surrounding events, during this preprocess the action of perceive and reason is executed simultaneously. The research paper is providing a brief and systematic study of different nature based approach required for the development of artificial intelligence.

II. EVOLUTIONARY SYSTEM

According to different dictionaries the evolution means gradual or continues development of something. In biology the concept of evolution plays an important dogma for the development of organism on the earth. Every living entity goes through the evolution process under the complex ecosystem. Each biological system or living organisms is the random interaction between different parameters, the characteristics of the system could not be predicted by the single entity. The theories of evolution system in life science help researchers to identify the consequences after the adaptation of different entities based on evolution process or natural selection. The basic mechanism of biological evolution consists with various activities; the objective of evolution is to transform the properties which were consisting by the old organism to modern organism. The evolution is responsible to maintain the similarities in life and the societies across the globe or between the different diversities of life under the different external environment. In other words the biological evolution reveals adequate modifications in decent population of organisms. The entire process is executed by the genetic inheritance, where genes are capable to encapsulate the ancestral properties.

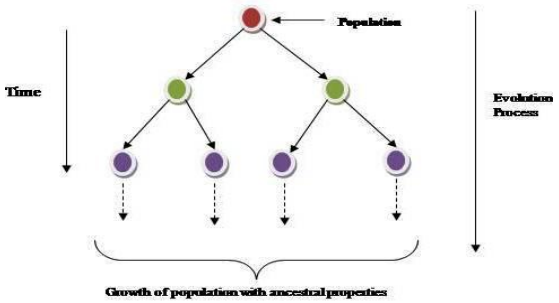

Figure 1 Evolution Process

The idea behind the evolution algorithm is summarized as given below:

- Population ρ is group of n distinct and well defined individuals.
- Due to external environmental causes, survival of individuals from population is one of the major issues.
- The concept of natural selection or survival of the fittest is deployed.
- Fitness of population is framed to select the best solution.
- To create candidate solution randomly the quality functions are used in best defined range of domain.
- According to this fitness, best candidates are adopted.
- The best candidates are used to reproduces the next generation of population by adopting recombination process or mutation.
- For two or more than two best candidates, the recombination operator is deployed to find the new candidate as solution.
- The process of mutation is adopted by one best selected candidate and it produces a new candidate.
- Deployment of recombination operator and mutation process produces a new set of solution according to fitness, which is encapsulated with the properties of old population.
- The mutation and recombination process is iteration process, which helps to reproduces population more refine and natural way.

In evolution process two external methods is strongly adopted in natural way, which is the basic requirement for the development of systems:

- Recombination and mutation operator which helps to create new population with diversity.
- Natural selection process which tries to adopt quality and fitness in new population.

The combined process of the best candidates and selection of best solution through fitness creates the constructive populations. It is an optimizing process to create appropriate solution sets. Due to external selection process it performs as the adaptation mechanism. In other words the fitness function could not be termed as objective function to pursue the optimization, it helps to express the requirements of environment for the next generation population with variety of qualities expected for the survival. This helps to increase the probability of survival of new candidates or population in external environment; also supports to increase the size of population with diversify properties or survival parameters. The population develops quality of adaptation of external environment in better way.

The evolution process is a random process, which is based on random probability distribution but could not be predict previously. The input of the probability distribution function is randomly selected by the external environment or nature. The probability of random selection of the candidate is based on the size of the population; if the size of population is smaller than the selection of a candidate is higher even it is weaker. The recombination processes of candidates are random, so the viability of produced candidate is random and it helps to implant more diversity in population. Similarly the process of mutation is also performed randomly to produce candidate from the self.

The pseudo-code for Evolution Algorithm is as given below:

- BEGIN
- INITIALIZE *population* ;
- DEVELOP population consist with defined and distinct candidates;
- EVALUATE each member or candidate of population;
- REPEAT
- UNTIL (till termination condition)
- DO
  1. RANDOMLY SELECT candidates for the parent;
  2. RECOMBINE randomly selected candidates in pair;
  3. MUTATE the product;
  4. EVLUATE the new candidates according the parameters of function;
  5. SELECT candidates for the creation of next generation population;
- OD
- END

The evaluation process follows the brute force approach which accepts the generate-and-test algorithm for the creation of candidate solution and diversified population. The evolution function accepts the fitness function of heuristic

nature to select the appropriate solution of required quality based on various operators. The exhaustive search process prepares the solution sets for next generation population which is infused by external forces.

The Evolution Algorithm (EA) is used to introduce the concept of evolution process to handle different computational problems. Evolution Algorithm (EA) helps to convert natural biological development process of organism into algorithmic form. The Evolution Algorithm (EA) is based on population, it is gathering of candidate solutions. Evolution Algorithm (EA) is deployed to use recombination operator to blend information of different candidate solutions for prepare the new one. The Evolution Algorithm is considered as stochastic approach.

The evolution algorithm consists of different components which are required to develop Evolution algorithm. The components are discussed below:

For EA the solution set is prepared for the original problem known as population. The population is defined with the help of individuals. All individuals of population is properly represented and defined with some basic characteristics. It is also known as candidate solution. The concept of population is to represent possible solutions. Diversity in population represents various solution sets of problem.

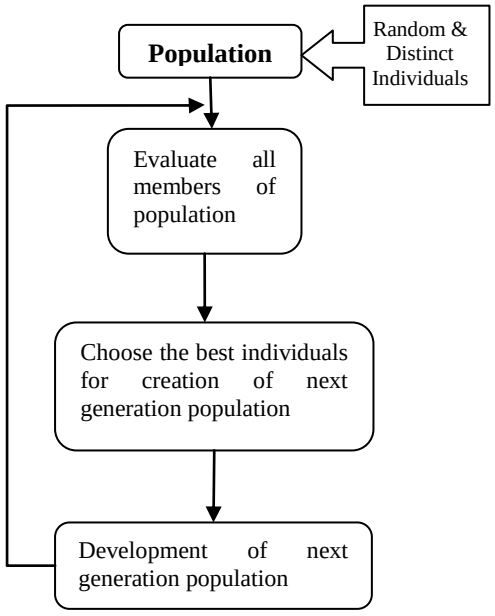

Figure 2 Evolution Algorithm Process

The individuals are evaluated through fitness function or evaluation functions. It is required to measure and represent the requirement for the solution sets or best candidates for the next generation population. The evolution function is also known as fitness function. Based on quality of candidates the best candidates are identified for the parent selection, which is responsible for creation of next generation population with best and diversified qualities. It is also termed as mating selection. After the section of best candidates for the role of parent, mutation and recombination operators are deployed for expansion of population.

Mutation is unary operator applied to one best candidate for deliver modified and desirable mutant. It is known as child or offspring. The binary operator is adopted by the recombination to generate new candidate for the next generation population. It is known as crossover. Further the replacement function is executed by the survivor selection method, which is applicable to differentiate among candidates according to their survival qualities. The survivor selection is also known as the environmental selection, which is responsible for replacement mechanism activated to replace non performing candidates or candidates with low survival quality. EA is based on Initialization process, under which the first population is created or seeded by randomly adopted individuals. The entire EA process is stopped when the termination condition is activated. Termination condition is executed when the system achieved optimal fitness level.

III. ARTIFICIAL LIFE

The Artificial Life is an approach to analysis and study the behavior of man-made system, it is also responsible to observer the characteristics of natural organisms or natural living system. It is artificially designed and implemented according to traditional biological systems simulated with the help of advanced software. The natural life is based on evolution process and based on chain relations among all the parameters. Biology based on scientific study approach of life. Every natural organism or life is dynamic model that constitutes different events simultaneously.

The Artificial Life is the form of life and synthesizes different processes, developed by human according to principles of original life. The concept of Artificial Life is the modern field of study which deployed by the systematic study of system biologically known as natural life. In central idea the biology studies the property of matter injected for the development of organisms whereas the artificial life is concern with the views of life as a property of organization of matter. The natural organisms are byproduct of biochemical machine of complex nature, spread over in different forms such as tissues, organs, membranes etc.

The Artificial Life adopts the organisms as group of small machines and performed simultaneously to create a system which is consolidation of simple, rule govern entities. The entities interact with each another in non-linear manner to support the global dynamics of system say Life. The natural life is executed on the basis of simultaneous and nonlinear interaction of entities without constrain of global controller based on behavior of particles. Artificial Life is based on concept of emergent behavior. All revealed interactions

among different entities in local level strongly influenced by the behavior and cognition level of particle.

The theme of Artificial Life (AL) is to develop emergent engineering for the system to handle different situations arises due to non-linear execution at micro level of system. The entire Artificial Life (AL) system is based on emergent behavior, which is required or arises during interactions. The Artificial Life approach deployed to analyze natural organism or life exiting in the world to adopt the behavioral frame of the components of natural living system. Artificial components develop behavioral repositories to store different behavioral mapping for execution purpose. After origination of artificial parts correctly the dynamics of system should similar to natural system. The AL follows the bottom up modeling approach required for the hierarchical development of system, which is similar to natural system.

The software tools are deployed for the study of natural life in synthetic approach. The traditional programming is based on predefined data structure, which is not favorable to handle the problem of AL programming. The programming approach recommended for the artificial life is based on dynamic behavior rather than final result.
The features of Artificial Life in computer based model are given below:

- The population is consisting of simple programs analogy of natural population.
- There is no single control or program responsible to direct all of other programs.
- Each program is designed to handle external situation witch arises in local level.
- Programs are also responsible to interact with other programs effectively.
- There is no global rule to govern global behavior of population.
- The behavior of each program is controlled in emergent approach.

Artificial Life is completely concern with the behavioral frame work as natural life. For the natural life the entire execution frame work is deployed and controlled by the natural system and this similar mechanism is recreated by artificial life. Artificial life (AL) is majorly concern with intelligent behavior. Behavior is the simultaneous requirement for the AL. Major concern with artificial life is to develop an algorithm for control mechanism of the system in global level. Concept of AL is majorly used in the field of robots control, behavior of robots, computer graphics, smart cities development, data mining, simulation techniques etc.

IV. BEHAVIORAL SYSTEM

Behavior is continues sequence of actions which is performed by the living organisms with the external environments during interaction. It helps organisms to decide the perceptions and develop the action plan for the future references. The behavior helps to develop pattern of different actions required during the interactions between the entities of organisms. Behavioral system encapsulated with sensory which helps to develop interaction between systems and a brain to allow simulate situations with external environment.
The deep understanding of natural behavior helps researchers to create process of artificial behavior required for robots. It upgrades the domain of human machine interaction effectively. The autonomous robots are designed to handle the external environment known as behavioral machine, proficient to execute itself in dynamic changing environment without human support. Now days the autonomous robots are created by the inspiration of natural biology. The behavior based autonomous robots or biologically inspired robots are completely inspired and fabricated according to natural intelligence.

The behavior of any living creature is based on the accumulated perception of day to day experience influenced by the external environment. There is a direct relation between behavior and intelligence which helps to develop deep learning among the creatures. The cognitive science is modern approach for development of understanding in the field of behaviorism. Cognitive science is the amalgamation of psychology, neuroscience and computer science to map the computational capabilities of human mind, helps to understand the logic behind the human intelligence. This approach is suitable for to chalk out the entire algorithm behind the intelligent behavior of natural organisms. It is also applicable to decode the computational intelligence of human mind based on logics and assumptions developed over the time influenced by the external parameters or hypothesis. An autonomous robot or intelligent machine is a kind of man made system based on artificial intelligence acts intelligently, which is appropriate for the circumstances. The intelligent machine learns from the adequate experiences, which is adopted from the flexible environments. Researchers want to translate natural behavior and logical perception techniques of human being into operational model compatible with computer programming. This research model approaches towards new dimension of knowledge engineering known as cognitive science. Cognitive science is amalgamation of neuroscience, computer science and psychology, which helps to develop the computational theory of mind.

Brooks (1986) proposes behavior-based robotics based on artificial intelligence and concept of robotics. Brooks (1991) supports the hypothesis that intelligent behavior is the resultant generated after the coupling between perceptions and actions. The actions are developed during the invoking of high level cognitive processes. The behavior based robotics is associated with the development of efficient robots applicable to handle real world problems. Arkin

(1998) describes that intelligent robots support the behavior based architecture consist with three different modules known as subsumption, action selection and voting. The modules work according to the external perception arises during behavior. Robots are based on biological model which is influenced by the living organisms.

V. BIOLOGICAL COLLECTIVE SYSTEM

The Artificial Intelligence is the main stream technique which is focused on the algorithm and software which is influenced by the natural cognitive abilities. The natural organisms are developed with help of micro units which is consist of limited resources. Organisms are one of the best specimen of collective systems perform collective phenomena, adopts adaptive functions that is not possible for individuals conducting in isolation. It is observed that behavior of individual is always influenced by the proximate members. The nature is flourished with the collective organisms indulge by collective phenomena and adaptive functions, which is required from coordinated movement to foraging.

The collective phenomena are required to associate with simple rules and local information provided by the adjacent members. These phenomena are not involved the global plan and central coordination. The members of the organisms are encapsulated with the simple rules due to its simple anatomy, but collective it handles the complex situations very intelligently and an efficient manner. The combinations of simple rules are associated without any global plan; it works according to local inputs provided by the neighbor of same capacity.

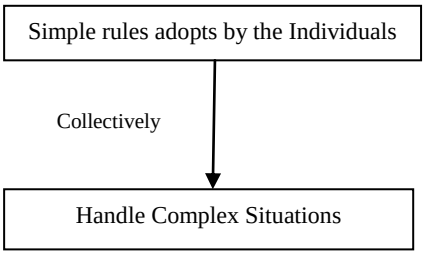

Figure 3 Collective Rules

The natural organisms or social colonies are collective system and accumulation of agents or members based on self-organizing collective dynamics. The survival pattern of collective systems is controlled by the agents according to interaction with another agent and external environment. Modalities of collective system are based on simple rules and adaptive functions. Adaptive property of the system makes it adjusted with unknown new conditions.

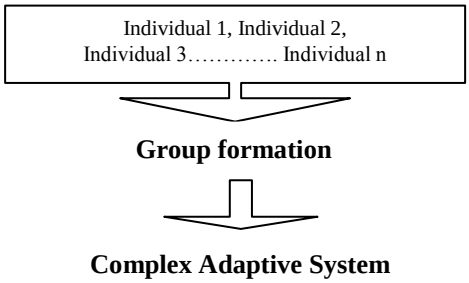

Figure 4 Adaptive System

The concept of self-organization describes a process where local interactions among the members create a complex structure of higher level. Cognitive abilities of members play an important role during the communication, observed that members are encapsulated with limited capabilities. Insect colonies are one of the best examples of collective systems; perform many complex works such as construction of nest, creation of beehives, foraging of foods or rules of swarm colonies. The social colonies of organisms is the resultant of the collective behavior and work of individual that is based on simple rules which is follows by the individuals with limited interactions infused by local information. Individuals not possess the global plan and global objective of the system due to the recourse limitations. The collaboration of simple behavior produces the complex behavior of the system which is adaptive in nature creates a flexible system which handles the external hurdles efficiently. After the deep observations of natural organisms it is found that behaviors are not genetically encapsulated, but developed after the interactions with the other adjacent individual in a self-organizing manner.

The self-organizing systems are works on the basis of feedback which is shared by the individuals with adjacent individual of the system. The feedback is classified into two subsets one is knows as positive feedback another negative feedback. Feedback helps to control the behavior of individuals. The equilibrium state of the self-organized organism is regulated by the reciprocity between positive and negative feedback. It is based on multiple states and multiple inputs. Positive and negative feedback of self-organized system produces many random modifications, which is known as bifurcation influenced the pattern or functionality of the system at the global level.

Stigmergy is a technique practiced by the individual of self-organized group trough the modification of external environment. The resultant of one individual work, affects the performance of another individual work. Grasse (1959) proposed stigmergy action with the help of termites and other insects practiced during the colony life. Ant colonies practice

stigmergy policy during the foraging of foods, ants share information with another neighbor ants regarding food source through chemical known as pheromone. It is deposited by the ants for their follower ants, the intensity of pheromone helps to decide the quality of food source. Stigmergy is also termed as the cue-based communication[2]. Aggregation is required by the self-organized system to control the activities based on positive and negative feedback mechanism. The aggregation appears when number of things is formed by the cluster for example fish schools, where huge number of tiny fishes swim together in close formation that could quickly change the direction of appearance pattern of group. Huth and Wissel (1992) advocated about the positive and negative feedback based mechanism for the fish schools. In fish schools the individual fish decides action according to the local behavior of adjacent fish. In self-organized groups mostly all individuals consist with similar set of behavioral rules or activity patterns. Perhaps some insect societies reveal the allocation of duties or division of labor among the specialized individual members for example beehives. The dynamic allocation of duties to individuals executed according to external environment based on adaptive functions.

The algorithmic models of natural collective self-organized system inspire researchers to develop machine learning techniques and robots. This approach is known as swarm intelligence (SI), where large collection of artificial limited resource agents able to solve collectively complex environmental problems or challenges. These collective systems works on emergent approach, the member agents tuned according to external variation in environment.

The solitary member of insect colonies are non-sophisticated and inefficient, they handle the complex jobs in cooperation. The insect colony behaviors which is completely coordinated developed by the simple interactions between the individuals. The collected activities practiced by the social insects are self-organized and executed without central control.

The swam intelligence (SI) is an approach to develop the swarm model. Swarm model helps to understand the inner mechanism or insect societies that generate collective behavior among the insects. Concept modeling provides a direction to undercover the actual happening in natural system.

In the domain of optimization, swarm intelligence techniques are successfully injected by the researchers and widely deployed with various applications in industry. Combinational optimization is a concept that consist technique of identifying an optimal object from the set of objects of finite size. For many problems the exhaustive search of feasible solution is not possible, it is executed on the domain of those optimization problems, in which the set of feasible is discrete or can be reduced to discrete, and in which objective is to collect the best favorable solution[5]. The combinatorial problems are most hard problems to handle in computing for both the theoretical and practical point of view.

The major problems for combinatorial problems are as below:

- The counts of combinatorial objects grow extremely and according to size of problem. It reaches up to unimaginable magnitude even if moderate size instance is deployed.
- It is challenge to develop unique algorithm to control such problems in exact period of time.

The ant colony optimization (ACO) and particle swarm optimization (PSO) are two known techniques of swarm intelligence suitable to get the approximate solution of optimization problem in rational period of computational time[1].

VI. ANT COLONY OPTIMIZATION (ACO)

ACO technique is inspired by the foraging method of ant colonies by which ants identify the sources of foods and collect it for the society. Ants of colony establish the communication and share information with adjacent members with the help of pheromones; it is also known as indirect communication between individuals. These practices help ants to indentify the shortest path between ant society and food source. ACO technique was deployed to solve the problems in approximate optimization; behavior of natural ants performed during the foraging is converted into algorithmic form to solve discrete optimization problems. The development of ACO is based on the observation of ant colonies, individuals of ant society is governed by the survival goal of colony. During foraging process ants search surrounding area for food in random principal. After identifying the food source the pheromone is deposited on the path for the other ant, this indirect communication is termed as stigmergy. Stigmergy process helps to define shortest path between food source and colonies. The intensity of pheromone is based on quality and quantity of food source.

ACO model is based on *graph theory*, the ant colony and food source both are considered as the vertex and the path between them is considered as the edges. The pheromones are deposited on edges for the communication purpose. The paths are used by the ants iteratively and pheromones are accumulated till the food available in the source. The natures of pheromones are chemical so it is evaporated after certain period of time. The process of continues evaluation of solutions or path between source and destination performed by the ants during foraging process. The pheromone quantity of paths is examined continuously with forging of food

sources. Dorigo (1999) proposed ACO framework, it helps to solve *combinatorial optimization (CO)* problems, and in first phase the finite set of solution components are developed. It is required to assemble solutions to proposed combinatorial optimization problem. Then the set of pheromone values are decided known as pheromone model. The pheromone model is probability model and one of the important mechanisms of algorithm. The pheromone values are used to generate solutions in probabilistic manner, after the assembling it final solution of the problem is proposed. The candidate solutions are continuously generated by the constituted probabilistic model executed simultaneously with pheromone model of ACO. The value of pheromone is updated according to candidate solution which is searched by the algorithm in the search space, if the probability of getting solution is higher in search space then pheromone is updated.

The ACO is deployed to solve many classical problems of optimization such as assignment problems, TSP, scheduling problems, graph coloring and maximum clique problem. ACO techniques are also applicable in some modern applications such as circuit design, routing algorithm, topology design of communication networks, bioinformatics problems. It is also useful to solve the problems in the field of continues optimization.

VII. PARTICLE SWARM OPTIMIZATION (PSO)

Kennedy et al.(1995) proposed population based stochastic optimization technique termed as particle swarm optimization (PSO) influenced by the behavior of animals such as fish schools, bird flocking or animal herding[9]. It is an approach which is useful to simplify the complex optimization problems. In PSO, every individual is known as particles and called as the potential solution; individuals search the optimal solution for problem. Each individual of the group advertise his current location with neighbor individuals. The locale of each particle is managed according to its velocity and the difference between its current best positions to neighbor position[8].

In PSO, the movement velocity of each individual particle is modified iteratively by it observed personal best position, and best position is estimated by its neighborhood. Each individual particle searches surrounded region identified by its personal best location or position and the best position from its adjacent member. Every particle consist with three different parameters 'momentum', 'social' and 'cognitive' which helps to establish equilibrium with the group embers. The PSO technique is helpful to handle the Multi-objective Optimization and Dynamic Optimization problems.

VIII. SWAM MODELS IN HONEY BEES

To solve different real world optimization problems, computer scientists introduced ideas which is influenced by the honey bee colony and based on agent-based algorithms. The honey bee based on the mechanism to simplify the multi-objective optimization problems to distribute available limited resources to various tasks under continuously changing external environment, colony maximizes its gain [7].

The honey bee colonies manage its day-to-day mechanism under following heads:

Labor Management The members of honey bee colony are morphologically uniform and encapsulated with specialized task talents of temporary nature. It helps members to face flexible external environment more effectively and adopts its responses to an ever-changing environment with efficient level of performance.

Communication Network The hybrid communication network is adopted by the honey bee colonies for the sharing of information among individuals. The signals and cues are deployed for the exchange of messages. Signals are direct method of communication in honey bee colonies such as waggle dance, tremble dances. Cues are another method of information sharing through the external environment, method of such communication is known as indirect communication. Both approaches provide an effective communication mechanism model among the members according to requirement of the environment. The mostly indirect communication is based on group to one approach and direct communication supports one-to-one approach.

Reinforcement Learning The honey bee colonies faces complex fluctuation situations based on external supply or internal demand. A strong feedback system is established to regulate and manage the commodity requirement of the colony. To handle such situation unemployed bees are recruited with required situational skill based on reinforcement learning[7].

Coordination Every honey bee colonies are consist with huge numbers of members, coordinated without central authority. The honey colonies are not based on the organizational hierarchy for the allocation of duties and responsibilities among the members. Each individual of colony choose the task which is required for the survival of the colony and the situational information is conveyed among the bees by the direct or indirect communication machenism.

Stochastic Selection of food sites The honey bee colonies supports optimize foraging techniques to save the resources. The food sites are selected according to their quality, quantity and distance between food source and colony.

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