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SWARM INTELLIGENCE TECHNIQUES WITH CONSCIOUSNESS AND COMMONSENSE IN ARTIFICIAL ECONOMICS FOR ENERGY CONSERVATION IN ENRICHED COGNITIVE ARCHITECTURE

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Abstract— Energy conservation is the challenging issue in cognitive architecture are efficiently handled by adopting commonsense, consciousness concepts with swarm intelligence techniques. An Enriched ECACECC (Enriched Cognitive architecture for conservation of energy using consciousness & commonsense layer) is proposed and designed. A commonsense Strategy and proposed algorithm in cognitive architecture are implemented in simulated Testbed. The result of performance ore and crystal evaluation, The Life Expectancy of Cognition versus BDI Agents and commonsense, consciousness with Swarm agents and Consumption rate of Fungus and Ore Collection and life expectancy are discussed. The results obtain from ECACE are compare with Society of mind Approach for distributed cognitive architecture (SMCA) agent's and shows that commonsense, consciousness with swarm agent's performance is better than SMCA performance in energy conservation.

Keywords— Energy Conservation; swarm Intelligence; cognitive architecture; artificial economics;

I. INTRODUCTION

The main purpose of this research is to understand, implement, and test the principles of human consciousness and commonsense in artificial economics of cognitive architecture. The research aims at proposing a self-configurable computational model of Enriched Cognitive architecture for conservation of energy using consciousness & commonsense layer for implementing and testing human consciousness and commonsense principles using a cognitive approach.

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The above cognitive architectures have simulated many cognitive tasks that are necessary for simulating consciousness on an agent. Hence, these architectures have a strong contribution towards the development of Enriched Cognitive architecture for conservation of energy using consciousness& commonsense layer (ECACCE), agent architecture proposed in this research work. The ECACCE proposed in this research paper has six layer architecture, the layers such as reflexive layer, reactive layer, deliberative layer, Swarm intelligence, consciousness and commonsense layer. The agents of each layer demonstrate different degree of commonsense and swarm intelligence techniques for the conservation of energy.

This research work aims at building intelligent agents that are highly conscious of external world and adopt commonsense and consciousness strategies to respond in dynamic environments. The paper flow start with introduction of need of swarm intelligent in energy conservation for artificial economics in cognitive agent is discussed in section 1, followed by identified related works on swarm agent with energy conservation in section II, proposed ECACCE architecture in section III, Strategies for Commonsense Behaviour in ECACCE and Algorithm of Commonsense in ECACCE in section IV Experimental design, setup are discussed in section V, detail implementation Result discussion with graphs are shown in section VI , comparison of SMCA with ECACE swarm agent performance are show in section VII and followed by conclusion and further enhancement were discussed.

II. RELATED WORK

There are many existing cognitive architectures that are built to test and implement cognitive capabilities of the human mind. Emotion Machine Architecture (EM-ONE) [96] proved human commonsense thinking capability in Robo verse environment. EM-ONE explains the scenario of situations involving physical, social, and mental dimensions for commonsense application. The Computational Model for Affect Motivation and Learning (CAMAL) [23-26, 55] architecture emulates affect and emotions.

The Society of Mind Cognitive Architecture (SMCA) [105,106] investigated the concept of mind as a control system using the "Society of Agents" metaphor. This architecture demonstrated how the economic concepts of natural minds can be simulated in artificial minds using fungus world testbed. The build of commonsense on machines, it must be represented in a computational form with programmable aspects.. Gordon (1999) gave large-scale analysis of the planning strategies of human beings which involves commonsense aspects [46,48].

He proposed formal knowledge representation for 30 cognitive functions that are clustered into memory, goal, environment, planning, and execution. This research work explains, investigates and demonstrates the commonsense, consciousness concepts in robotic applications using swarm intelligence. This work describes how robots convert their learned knowledge into commonsense, consciousness knowledge over a length of the time in a ECACCE (Enriched Cognitive architecture for conservation of energy using consciousness & commonsense layer). EM-One architecture (Singh, 2005) explains the scenario of situations involving physical, social, and mental dimensions for commonsense application & SMCA (Vijay Kumar M V, 2008) investigated the concept of mind as a control system using the "Society of Agents" metaphor .This proves that commonsense tasks are performed faster and uses less resource. The performance of agents can improve all the routine tasks, which are conscious.

III. ENRICHED INTELLECTUAL ARCHITECTURE FOR CONSERVATION OF ENERGY LAYER WITH COMMONSENSE (ECACECC)

The ECACECC is a six-layer cognitive control architecture developed for building artificial minds of agents that are conscious in new and dynamic environments and exhibit commonsense similar to human. The layers included are reflexive, reactive, deliberative, swarm intelligence, conscious, and commonsense as shown in fig 1. The agents of each layer exhibit different levels of intelligent behavior in the domain-specific tasks as they have varying cognitive capabilities.

The architecture designed utilizes different types of memories such as working-memory, perceptual memory, episodic memory, declarative memory, and procedural memory. Each layer below provides a service to the layer above and hence the functions coded in the lower level layers are invoked and controlled by functions in the layers above. This architecture is used for designing all six type agents as shown in figure 1.

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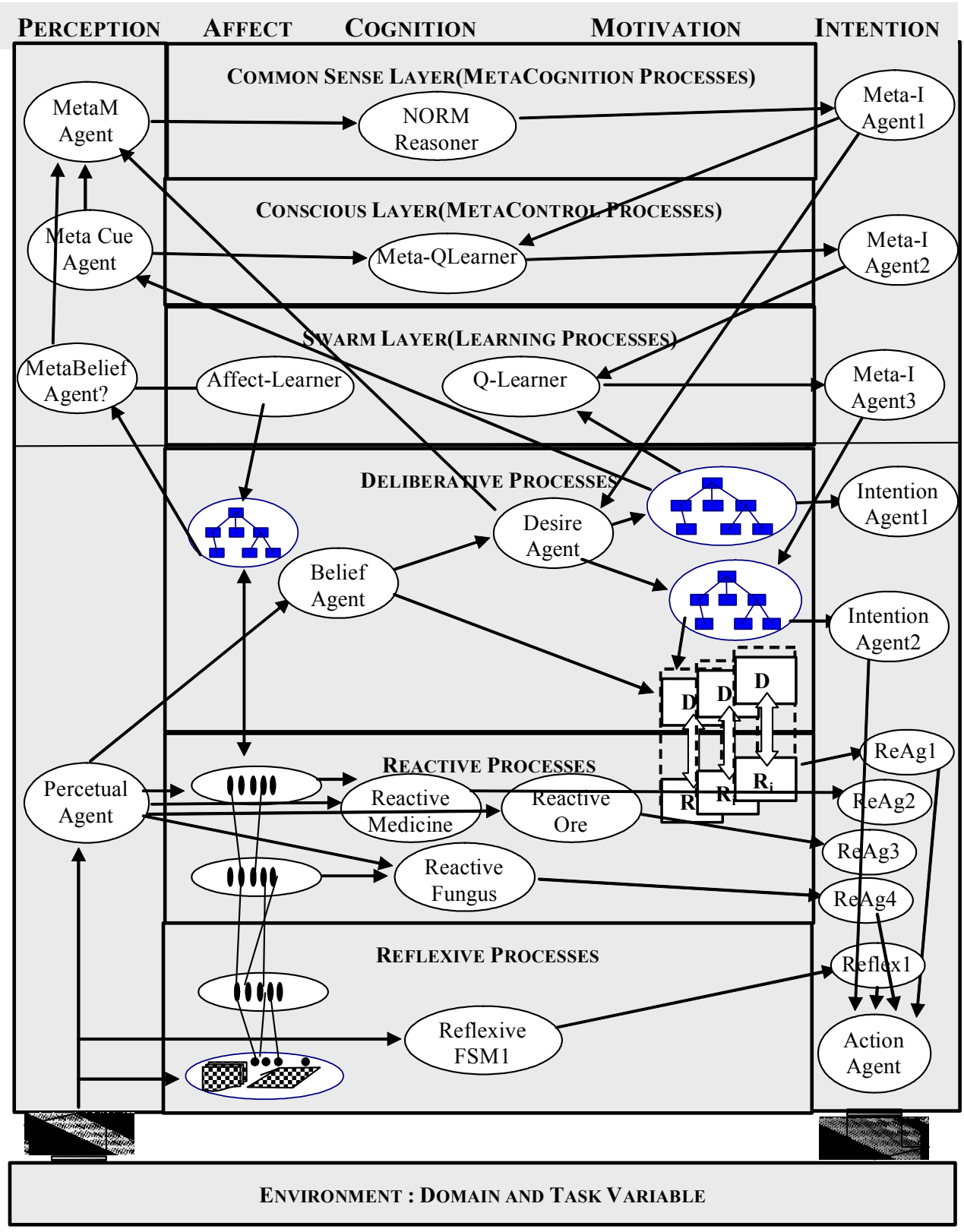

Fig 1 ECACE architecture using SMCA ((Dr.Vijayakumar, 2008)

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IV. STRATEGIES FOR COMMONSENSE BEHAVIOUR IN ECACECC

These strategies enable agents to demonstrate social behaviour by moving in a group when the attacker is near. The commonsense belief here is that an attacker cannot attack if they are in a group. They do use safe places for escaping as commonsense where the attacker cannot kill the agents. These strategies make agents intelligent by not indulging them in emotions such as fear when threat level is high. The strategies adopted by commonsense agents in multi-agent and single-agent environments are explained below:
Commonsense Strategy 1(CMST1) shown below is adopted by agents when the threat level is high and is in single agent environment. This strategy makes an agent to use its commonsense to escape from attacker by moving to nearby safe places.

Strategy="move to safe zone"
Motivation: escape from attacker when alone
Precondition:Distance _to_attacker (Agent)<2 grids
Threat_level=High and Agent_count=1

The CMST2 shown in the below is adopted by a commonsense agent in multi-agent environment. If the threat-level is high, the strategy enables the agent to find safe zone or move to join a group. The strategy determines the best possible way to escape from attacker using commonsense. The motivation and desire here is to survive by escaping from an attacker.

Commonsense Strategy 2(CMST 2)
Strategy="Find which is near? safe_zone or Agent"
Motivation: To escape from attacker
Precondition:
Distance_to_nearby_(Agent)<Distance_to_safezone(Agent)
Distance_to_attacker (Agent) <2 grids

V. ALGORITHM OF COMMONSENSE IN ECACCE

STEP1: Select the agents with agents strategies (Commonsense Belief set)
STEP2: Commonsense agents have self-awareness in their internal states such as belief, desire and intentions (BDI) with knowledge base.
STEP3: The Commonsense agents dynamically change their attention switching in commonsense agents.
STEP4: The deliberative agents converted to commonsense agents adopting the learning method to memorize the experience with knowledge base.

(1) Metabolism > Low,
Searches the nearest medicine to collect to lower the metabolism by their reactive mechanism. Uses the Reactive Medicine,
Find the nearest Medicine by their distance,
Select the direction towards nearest Medicine,
Move towards Medicine direction | left| right |Up| down.

(2)Energy Level <= 40 (Threshold value)
Generate PerceptionList [NewDirection] If the List of options for the agent in a next move are { crystal, golden ore, ore, attacker-agent, free space, obstacle, trap}

a. If an attacker present in a next move, move-ahead 2 steps in opposite direction
b. If a crystal present in a next move, consume and increases the energy-level by 2 units.
c. If a golden ore present in next move, consume and increase energy-level by 4 units
d. If a ore present in next move, collect and increase ore count by 1 and give energy by 1 unit
e. If an obstacle present in next move, take a turn to avoid the obstacle
f. If no move possible, back track to previous state and repeat step 2

The agent desire to move towards to fungus to avoid the hunger condition or their death (Physiological oriented) uses the Reactive Fungus, Finds the nearest Fungus by distance formula,
Select the direction towards nearest fungus,
Move towards Fungus type direction | left| right |Up| down.

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(3)Energy Level > 40 (Threshold value)

Reactive Ore (Goal based behaviour move towards nearest Ore)
Find the nearest Ore
Select the direction towards Ore.
Move towards Resource direction | left| right |Up| down.

STEP5: Switches to belief desire intention agents for agents performance
STEP6: The deliberative agents broken down the reflexive and the reactive behaviour
STEP7: Reach the goal
STEP8: If energy level is below threshold and no-food parameters in the perceptual range then move to explore food
STEP9: If energy level is 0 the agent dies

VI. DESIGN OF EXPERIMENTAL TESTBED

The animate testbed used for analysing consciousness and commonsense thinking on agents is simulated by creating agents as close as possible to the intelligent animals in natural ecosystem. The term "animate" is used for agents in ECACCE testbed to signify that their control systems built is above animal cognition and below human beings. These agents are built with necessary and sufficient subsystems such as sensory, planning, and action. The sensory subsystem is associated with perceptual memory and used for perceiving objects and creates associations with other objects in the environment for goal achievement. The planning subsystem is elaborated into emotion, cognition, and motivation stages, which is a need satisfaction model to meet the goals. The action subsystem generates the sequence of actions based on the strategy chosen in the planning stage. The simulated model has agents that demonstrate human and non-human mind aspects from simple reflexes to more complex behaviour.
Every living system's behaviours are driven by primary needs and their cognitive capabilities that are evolved to satisfy the needs. Experiments are conducted to study the cognitive capabilities of agents that emulate conscious behavior in agents. The performance and intelligence of animates are analysed based on their survival rates.

TESTBED SETUP

The ambient testbed is implemented using SWI-Prolog 6.6.4.The Ambient testbed experiments include cognitive and psychological aspects on the architecture. The testbed is created to have dynamic parameters as shown in the figure. There are four buttons created. Definition button is used to select all the parameters and agents, configure the agent's initial energy and number of cycles to perform. Exp button is used to start the experiment where an agent starts the assigned task in the environment. Movement is a continuous process. Cycle button is used to see agents every move only on click. Each time the cycle button has to be clicked for agent to move. Quit button is used to exit from the graphical user interface (GUI).

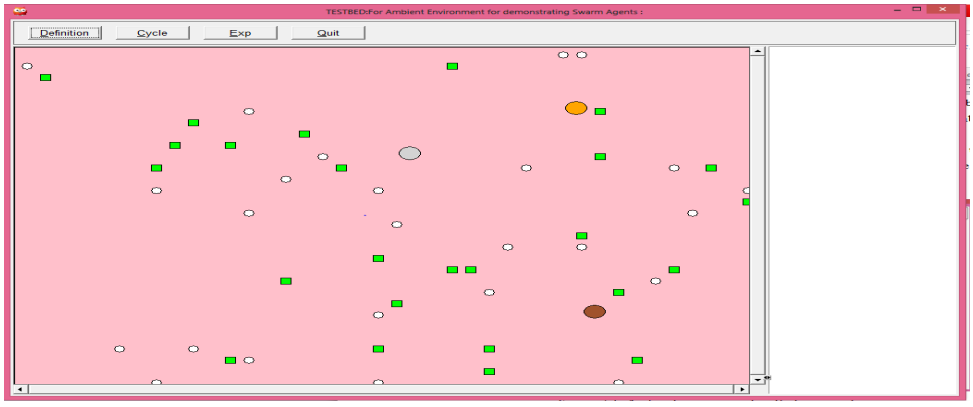

Fig 2: Simulated environment

The experiment outcomes show the performance of these agents which is swarming ambient environment. The results will show that communication alone is not sufficient for individual performance in a mixed group, but perhaps the behaviour of a person plays the role motivation. The outcomes of these experiments provide the cornerstone solution or a solution that is partially the problems stated in this paper ECACE architecture is made to always check exactly how individual agents will act in friends, how agents' behaviour will have an affect the team performance.

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Agent behavior is analysed utilizing various metrics like competition, life expectancy together with a connection that is social respect for the environment and its parameter. The simulation shows the interaction that is complex different variety of agents, agents' behaviour with respect to make use of of power and time for you to make decisions. The ECACE email address details are simulated for:

1. Performance of swarm agents with respects to quantity of diamonds collected.
2. The life expectancy of swarm agents with regards to number of rounds lived.
3. The energy distribution of swarm agents: at each and every cycle how agent's power is getting reduced as well as for use of meals how energy of on agents is getting increased.
4. Comparison of performance of agents and thus concluding the extremely motivated agent much less representative that is inspired.

The cycle is fixed for the agents. Here to test the number of rounds considered is 500 and energy that is initial each representative is 100 units. Wide range of meals considered is 25 pieces and diamonds 25 pieces. Each representative is experimented for the period that is same exact same initial energy, same resources like metals and diamonds. The input value of every parameter defines the configuration file. The output file provides the details of each agent. Based on the information being statistically for every agent, the experiments are carried out. The following statistics had been gathered: life expectancy, diamonds gathered to compare a result of each agent. The agent's performance that is totally calculated predicated on range diamonds gathered and centered on endurance. The experiments conducted many amount of times, by taking into consideration the input that is same. The results which can be final are considered by firmly taking top data out of the test carried out. The data is going to be plotted regarding the sheet that excels. Then graphs are created.

VII. RESULTS DISCUSSION

A. Performance of commonsense, consciousness in Swarm-Ore and crystal versus BDI Ore versus Reactive Ore Agent

The results of this figure 3 show that commonsense, consciousness in Swarm-ore maintain a higher level of life expectancy than BDI-ore agents and reactive agents.

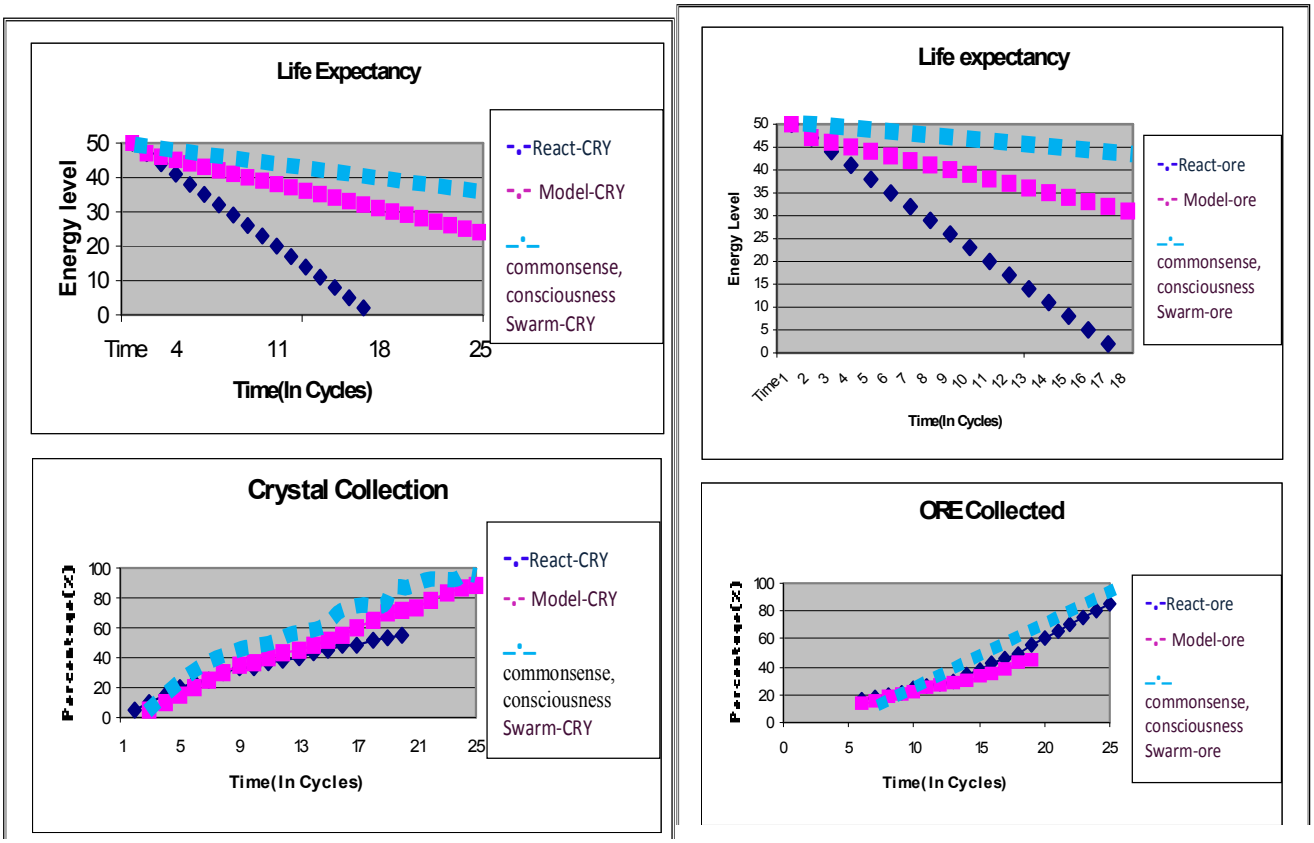

Fig 3: Performance Evaluation of Reactive verse BDI verse swarm Agents ore and crystal

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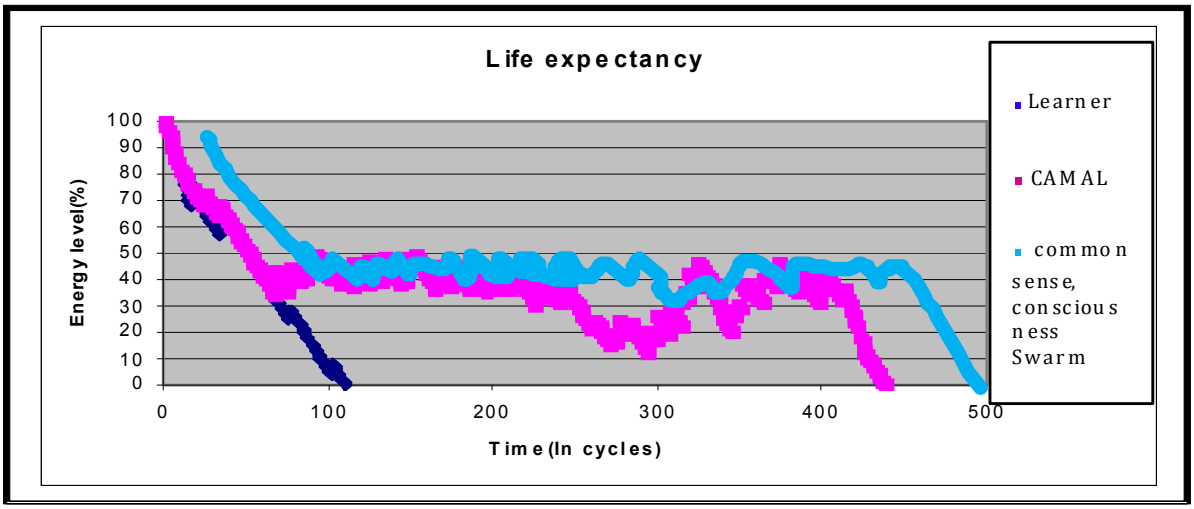
Commonsense, consciousness in Swarm agents manage the energy level of 94%, BDI agents manage 80% and reactive agents manage 0%. The reactive agent dies in 18 cycles out of the 25 maximum cycles assigned. The commonsense, consciousness in swarm-ore agent's collects 94% of ore as compared to BDI-ore (BDI with goal towards ore) agents collect 83% of ore (resource) and 42% of ore collected by the reactive agent.

Similarly commonsense, consciousness in swarm agents manages the energy level of 97%, BDI-crystal agents manage 84% and reactive agents manage 0%. The reactive agent dies in 18 cycles out of the 25 maximum cycles assigned. The commonsense, consciousness in swarm-crystal agent's collects 97% of crystal as compared to BDI-crystal (BDI with goal towards ore) agents collect 84% of ore (resource) and 55% of ore collected by the reactive agent.

B. Study Two (Experimentation on BDI models)

As shown in figure 5, commonsense, consciousness in Swarm agent manages to live up to 490 life cycles as compared to BDI agent manages to live up to 438 life cycles. The commonsense, consciousness in swarm agent shows a complete control mechanism in managing an energy level of 50 (assigned threshold or decision variable) compared to BDI agent(CAMAL) as 40 energy level, and trying to manage the same line for the maximum time of its life cycle. The agents will exhibit optimal decision making capabilities near the decision boundary. The life expectancy of the two types of agents is shown below. The cognition (reflexive-learner) agent manages to live up to 110 life cycles in a fungus world environment.



The resource (ore, golden ore and crystal) collection of the simple cognition, BDI agents and commonsense, consciousness in Swarm agents is as follows: cognition agents managed to collect 12 pieces of ore, BDI agents managed to collect 95 pieces of ore and commonsense, consciousness in Swarm agents manages to collect 99 pieces of ore . Graph 8.5 illustrates agent decision making capability at the threshold value. If an agent acquires more than the threshold or predicted energy level, then agent tries to collect ore. If the agent has a lack of energy, then it collects fungus, from their hunger condition.

Figure 6 shows the fungus consumption rate of cognition, BDI agents and commonsense, consciousness in Swarm agent in their lifetimes. The cognition(reflexive-learner) agent managed to collect 6 pieces of fungus , BDI agent are managed to collect 74 pieces of fungus and the commonsense, consciousness in swarm agents managed to collect 84 pieces of fungus. As figure 6 illustrates, in the initial stages, the (reflexive-learner) cognition agent and the BDI agent was found to collect more fungus than the commonsense, consciousness in Swarm agent. The commonsense, consciousness in Swarm agent was not concerned about fungus in this stage. Agents in the initial stage born energy with medium metabolism. The commonsense, consciousness in Swarm agent collects the medicine to decrease metabolism. Agents, once they achieved low metabolism by collecting required medicine, then it does not concerned about medicine.

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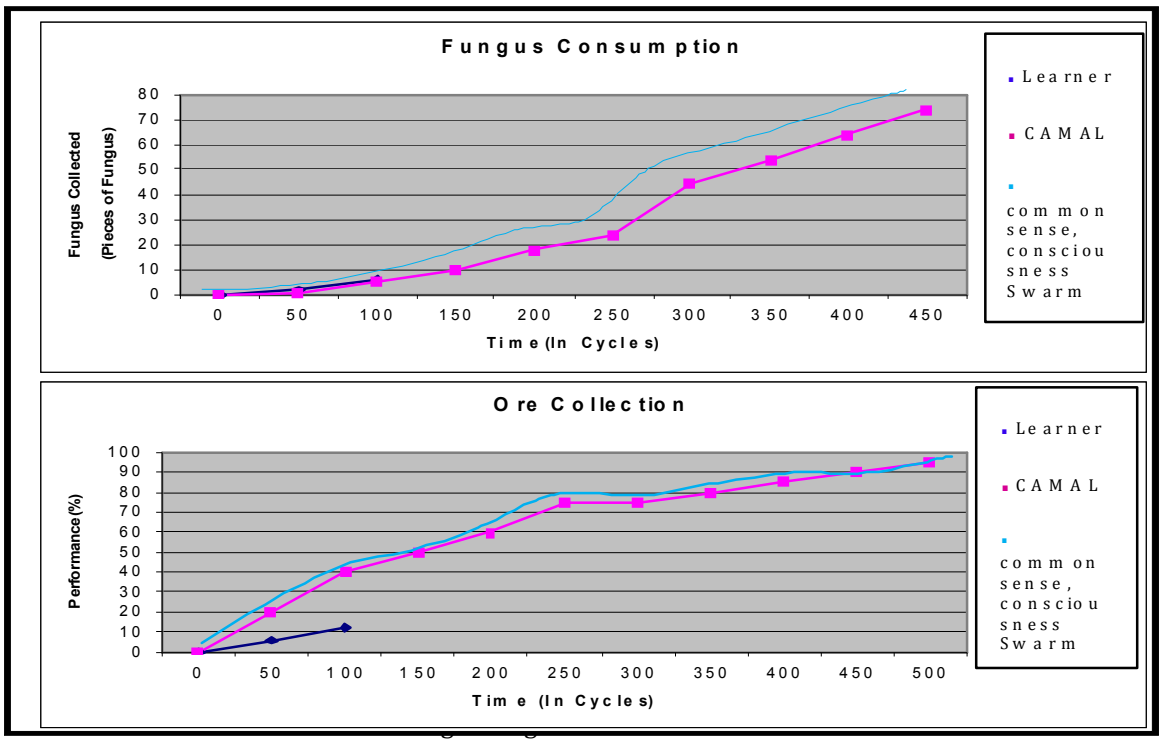

VIII. COMPARISON OF ENERGY CONSERVATION EVALUATION IN SWARM, CONSCIOUSNESS AND COMMONSENSE AGENT

To compare the results for each agent, the following statistics were collected: life expectancy, fungus consumption (including standard fungus, small fungus and bad fungus), ore (standard ore and golden ore), crystal collected and metabolism. The life expectancy or age of the agent is noted, along with the agent's death (or age after the end of the maximum cycles or time). The agent's total performance will be calculated by amount of resources (ore, golden ore and crystal) collected, and based on life expectancy. Three sets of experimental combinations were created :(1) reactive versus deliberative or BDI agents; (2) experiments on BDI models; and (2) cognition, BDI, and metacontrol versus metacognition.

TABLE 1: ENERGY CONSERVATION EVALUATION FOR 10 REPETITION

Number of repetitions	Swarm intelligence	Consciousness	Common sense
1	1	1.5	1.8
2	1.5	1.7	2.1
3	3.5	3.7	4.4
4	4.5	5.1	5.5
5	5.6	6.1	6.5
6	6.6	7.1	7.6
7	7.2	7.6	8.5
8	8.3	8.7	9.2
9	9.3	9.5	9.7
10	10.4	10.7	11.3

Experiments are conducted to evaluate the performance of proposed ECACCE in terms of energy efficiency agents. The performance of energy is evaluated considering varied repetition cycles.

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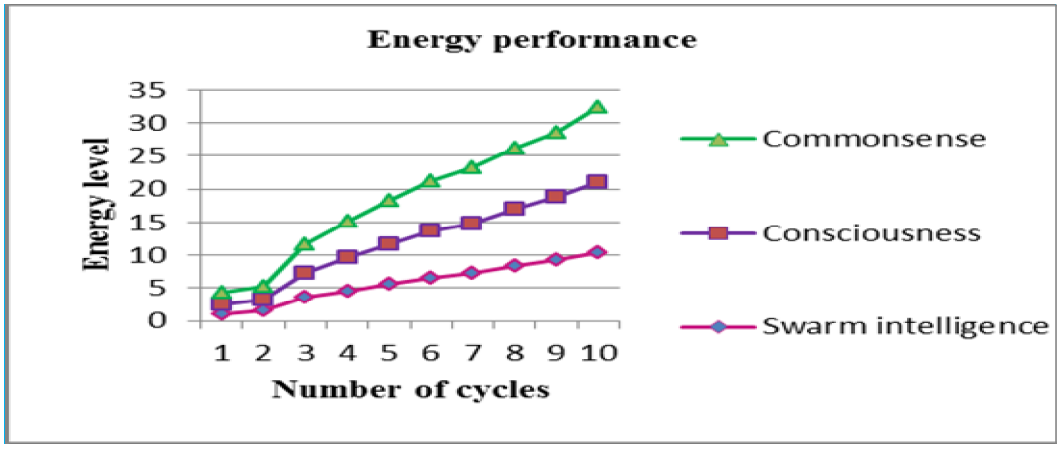

Fig 7: Agent performance evaluation considering 10 repetition cycles.

TABLE 2: ENERGY CONSERVATION EVALUATION

Number of repetitions	Swarm intelligence	Consciousness	Commonsense
1	1.3	1.5	1.8
2	1.5	1.7	2.4
3	3.5	3.7	4.4
4	4.5	5.1	5.5
5	5.6	6.1	6.5
6	6.6	7.1	7.6
7	7.2	7.6	8.5
8	8.3	8.7	9.2
9	9.3	9.5	9.7
10	10.4	10.7	11.3
11	11.3	11.6	11.8
12	12.2	12.5	12.8
13	13.1	13.4	13.6
14	14.2	14.3	14.5
15	15.2	15.5	15.6
16	16.2	16.4	16.8
17	17.2	17.4	17.7
18	18.3	18.5	18.9
19	19.2	19.5	19.8
20	20.3	20.6	20.9

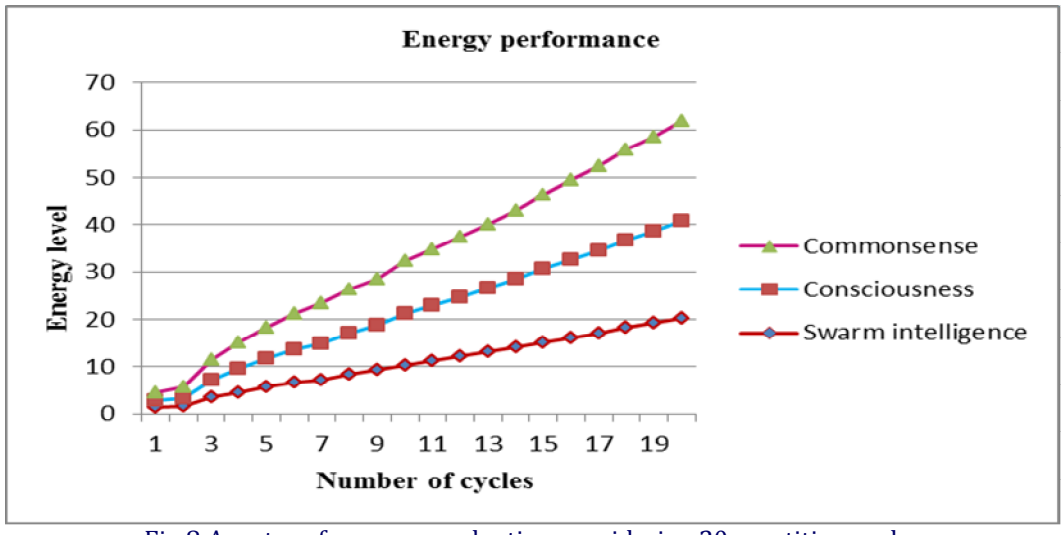

Fig 8:Agent performance evaluation considering 20 repetition cycles

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The consequence of the energy is shown by this graph of every representative at every period. Each agent gets the charged power that is predetermined. The setup opportunity for energy move of a representative, the agent loses its energy by two products. The results are captured from the agent's behaviour in handling their inner states in critical conditions. All agent types are evaluated for energy-level maintenance. These agents are separately compared for energy level as they consciously monitor energy level and use the same belief set. The commonsense agent maintains its energy level on threshold, and does not consume good fungus unless its energy level drops below threshold. These agents maintain better energy-level compared to normal energy-conscious agents. The performance is evaluated using the SMCA architecture and above shows that the ECACCE architecture with addition of common sense agents increase the conservation of energy. The common sense is a result of psychological processes of ongoing events to exhibit good behavior in the performance of given tasks

IX. CONCLUSION AND FUTURE SCOPE

The main conclusions of the study may be presented in a short Conclusion Section. In this section, the author(s) should also briefly discuss the limitations of the research and Future Scope for improvement. The research work proposes novel cognitive architecture for consciousness and common sense thinking called ECACCE to achieve the objective. The architecture is built with six-layers-five-columns such as the reflexive layer, reactive layer, deliberative layer, swarm intelligence layer, conscious layer and common sense layer. The conceptual mechanisms of consciousness and common sense have been implemented as mental processes in each layer of this architecture. The BDI model at deliberative layer, used for reasoning and planning, are updated in every cognitive cycle after evaluating for their truth value that can change due to some external events.

The research work proves that many aspects of consciousness and commonsense thinking can be simulated on agents, which in-turn can help build such machines in real. The research experiment conducted has progressively achieved the results required to justify the outcomes. The cognitive functions such as depiction, attention, attention switching, emotions, beliefs, intentions, desires and learning are simulated on agents. In this research work the animate test bed is successfully implemented as a computational tool to measure the performance of agents to meet the objective. The executive behaviour of ECACCE agents is demonstrated in their ability to switch from energy maintenance to threat management to meet the immediate goal of survival. In the comparative study, the research concludes that consciousness and commonsense aspects can improve the performance of agents in critical for both energy.

FUTURE WORK:

The research is designed for simulated agents with a bounded environment and fixed parameters. This work can be extended to machines to study the real behaviour. The work can be extended to defence systems as the future warfare is between machines and technology. The strategic planning systems used in this work consider the proactive attitudes such as beliefs, desires, motivations, intentions, and emotions that help replace human resources in defence systems. The environment is modestly designed with few constraints. The agents can be assigned some goals for which they can demonstrate competitive behaviour in a group. This can be extended to use reinforcement learning methods or biologically inspired learning methods that can lead to the optimization of the performance of agents. The conscious actions are costly events as they require many levels of reasoning, and commonsense is considered to be less costly as it can be executed as a complex reflex. Over a period of time most of the conscious tasks can be scaled down to automatic commonsense actions. This can also be addressed in future research.

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