Computational Test Beds for Synthetic and Robotic Agents

K.R.Shylaja, M V Vijayakumar, Darryl. N Davis, E V Prasad

ABSTRACT - This paper describes how to setup frameworks for testing computational theories and performance of robots. Test beds and benchmarks are mainly used as metrics to measure and compare the performance and outcomes of robotics and cognitive architectures. Artificial economics simulation concepts are taken as an example to demonstrate working mechanisms in fungus world testbed set up. The metrics used in this example are associated with the principles of artificial economics in animal cognition.

This research is to understand the settings of testbed and robotic environments. The experiments conducted on these testbeds allow us to understand the principles of natural minds and adopt these principles in a simulation and real environments. This approach necessarily requires the design and test of a range of simple to complex computational agents. The developed micro-agents in a fungus world testbed are designed to investigate artificial minds for animals and synthetic agents, drawing on qualities found in the natural minds. Qualities such as level of decision making, its cost function and utility behavior (the microeconomic level), physiological and goal oriented behavior are investigated.

Keywords: Testbeds, SMCA, fungus world testbed, Roboverse, ASIMO and ROBO-CAMAL

I. INTRODUCTION

The AI era started with John McCarthy, who named "Artificial Intelligence" as the new topic for the 1956 Dartmouth conference. At the same conference, Alan Newell, J.C Shaw, and Herbert Simon demonstrated the first AI program (Logic Theorist) that could construct logical proofs from a given set of premises. This event has been interpreted as the first example of a machine performing a cognitive task. A cognitive task is considered to be an element of the mind. The mind is a core concept for the field of cognitive science. Cognitive architecture is an embodiment of the scientific hypothesis of human and nonhuman cognition. Cognitive architectures are designed to be capable of performing certain behaviors and functions based on our understanding of human and nonhuman minds [2][3] [5] [11] [16].

Testbeds and benchmarks are mainly used for simulating, comparing architectures and outcomes in the field of robotics or cognitive architectures. Pfeiffer [14] describes the fungus eater concept as a testbed for simulating models in emotion psychology. The testbed environment allows the principles and behaviours of a robot or simulated animal or any artificial mind simulation to be monitored, measured and compared [13].

II. TESTBED AND BENCHMARKS

Testbed and benchmarks are used as simulated environments, with synthetic agents to compare the behaviour of simulated robot or an artificial mind simulated using any one of the cognitive architecture. A testbed is a development environment for experimenting and implementing standard tasks. The testbeds are the environments, where standard tasks may be implemented, observed and measured. In addition to the environment, it provides a method for data collection, the ability to control environmental parameters, and scenario generation techniques [6]. Testbeds provide a metrics for comparing the agent architectures.

The main purpose of a testbed is to provide metrics for evaluation (objective comparison) in testing agents. Hanks [6] define Benchmarks precisely as standardized "tasks". A task is a job given to a robot to perform, and the standard is a benchmark accepted by a significant set of experts in the same field. Precise means a mission goal and limited constraints in the execution environment [4]. According to Dillmann [4], the Hanks definition for benchmarks is lacking in terms of "development performance metrics". A benchmark should have the following features: repeatability, independence and unambiguity. Benchmarks can be measured using two types of metrics: (1) the analytical method, for observing a system's performance and (2) the functional method, to observe the performance of a

K.R.Shylaja is wih Dr. Ambedkar Institute of Technology, Bangalore, India (email: tejushyla@yahoo.co.in)
M V Vijayakumar is with New Horizon College of Engineering, Bangalore, India
Darryl. N Davis is with University of HULL, UK
E V Prasad is with JNTU, Kakinada, India

specific problem based on a benchmark score [4]. According to Hanks [6], benchmarks are used for comparing the architectural performance of the standard tasks. The results of different architectures can be compared and measured, from standard tasks. Artificial intelligence contains standard tasks for AI problems.

III. SIMULATION TESTBEDS

Some of the testbeds used for testing the performance of simulated synthetic agents have been discussed below.

An important issue in developing testbed includes complexity, metrics, flexibility and the ability to perform well in different situation. There are many examples of developed testbeds. Those relevant to this research include Packman [12], Tile world [13], and fungus world [15]

Packman:

SOAR(State Operator Action and Result) capabilities are demonstrated using packman testbed. The packman testbed consists of a pack-man like agents (eater), moving around the board or environment. The board is filled with 2 types of food: (1) bonus food and (2) normal food. The agent receives as a reward of +10 for moving into bonus food, +5 for moving into the normal food and 0 for moving into the empty cell in environment or grid board. Agent's capabilities tested by giving different skills including reinforcement learning [12].

Tile World:

Pollack and Ringuette [13] initially introduce tile world testbed in 1990. Tile world is a highly parameterized environment, and this can be used to investigate reasoning an agent [9]. The tile world is an abstract testbed designed for experimenting with multi agent architectures in dynamic and unpredictable environments. Tile world is a two dimensional grid on which are located different kinds of parameters. The parameters are tiles, holes, obstacles and a gas station or energy source. In simulation part, the object can appear and disappear. The parameters can be controlled with variety of characteristics associated with the objects in an environment. The original tile world consists of a grid cells (squares) on which different objects can exist. The agent can move up, down, left and right. The goal of the agent is to collect a tile and move a tile to fill the holes. A hole has an associated point value. Each hole may consist of three cells on the grid, and may have a total point value of five. Once the agent completely fills the hole, it earns the points. The overall objective is to gain as many points possible. Tile world simulations are dynamic, and the environment can change continuously [9].

Fungus world:

Toda[17] compared a "complete system" with a microcosm environment. The fungus eater is a simulated robot used for factious mining. It was sent to a planet called taros to collect uranium ore. The fungus eater can run out of energy and needs to collect fungus to replenish its energy store. Uranium and fungus usually not found in the same place. They will keep a certain distance from each other in order to avoid collision [21]. Pfeiffer [14] assumes: (1) movement or locomotion using legs, (2) collection or consumption using arms and (3) decision making using a brain. Fungus eaters are synthetic artificial agents and a particular species of amimats. Animats can be productively viewed from a designer perspective. Masanao and Toda [17] invented a new fungus eater testbed, for simulating artificial synthetic agents. Multiple agents can present in the environment at the same time.

As shown in figure 1, Toda proposed the use of micro world (a micro cosmos) for the purpose of modelling mechanisms and for collecting empherical data [20]. The animats approach will play an important role in the design and experimentation on intelligence and cognition. The fungus world environment and working principles allow a robot or any artificial mind to exhibit a specific behaviour in a specific environment[13],[14] describes the fungus eater concepts as a testbed for simulating models in emotion psychology. The fungus world environment allows the principles and behaviours of a robot or simulated models of artificial minds, which can be monitored, measured and compared [14].

Applying techniques, mechanisms and concepts on a test bed depends on the goals. Fungus eaters are complete autonomous creatures sent to distant planet for collecting ore. They have to think and eat a fungus to maintain an energy level for their survey of the world and to show best performance (i.e. to collect ore). The performance can be measured in terms of two perspectives: (1) the engineering perspective, which counts number of ores collected in a particular time cycle and (2) the cognitive perspective, which looks at managing the energy level and metabolism level sufficiently to allow surveying [14].

ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

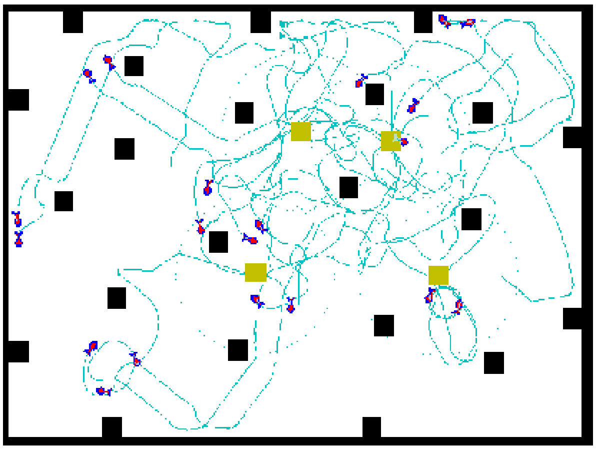

Fig 1. Toda's Simulator test bed

IV. ROBOTIC TESTBEDS

An agent or a robot existing in a physical world, perceives its environment through sensors and acts on this sensory input to achieve some defined goals. The robot environment may be static in which the physical world remains unchanged or it may be dynamic where the agent may encounter an unexpected obstacle or object in its environment. The objects in the real physical world which makes the robot environment are predefined as knowledge in the robot. We discuss some of the static and dynamic environments used for real robots.

Roboverse Testbed for EM-ONE architecture:

EM-ONE architecture originated from Marvin Minsky's "emotion machine" architecture [16]. EM-ONE architecture was proposed by Minsky and his student Singh [16], from MIT media lab. EM-ONE architecture for commonsense computing, that is capable of reflective reasoning about situations involving physical, social, and mental dimensions. EM-ONE architecture involves complex interactions among the several "actors" along with physical, social, and mental dimensions. EM-ONE uses a static environment for table building called Roboverse.

Roboverse is an artificial environment populated with actors of rigid body physics. The environment contains modular components such as sticks and boards. These components can attach to one another at their endpoint and corners. The simulated robots called actors roughly looks like human shape with single arm. The arm of the robot looks like an inverted pendulum. The hand part of the arm acts like a magnet, which can be switched on or off. This can attract the near by object. The robots are mounted with wheels to move around in the environment. The movement of the robot is controlled by controlling the torque of simulated motors at their joints.

The environment has many solid geometric shape objects. These objects on colliding move according to Newton's law. This law also determines the minimum force required to move an object in the environment in a particular direction.

The robots are simulated with synthetic perceptual system having many perceptual predicates. These perceptual predicates define the environment state, current state of object, object identification, movement, turning and action created by other actors in the environment. The robots apply these perceptual predicates to create an action in the virtual world.

The Roboverse environment has robot actors, one is pink in colour and the other is green. The green robot tries to build the table by using the sticks and partially built tables available in the environment.

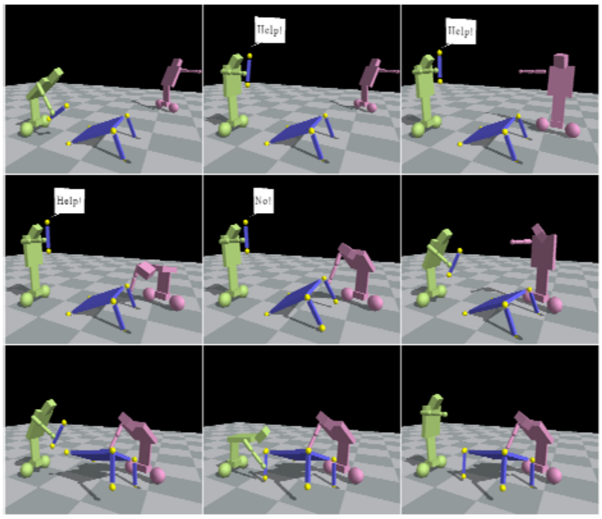

Fig 2. Singh's Table Building Mechanisms

ASIMO Robotic Testbed:

Asimo is a more advanced humanoid robot looks like an astronaut with a backpack. The robot is designed mainly to help and live in harmony with in human living space. Asimo is designed and developed by Honda's Research and Development lab. The latest Asimo with more sophisticated feature was released in 2005 [7].

Asimo is having two legs, two arms and a neck attaching the head with 34 DOF (Degree of Freedom). Each DOF is controlled by a servo motor. The robot size and weight is chosen to make the robot working comfortable in human operating environment. Asimo's height is 130cm and its weight is 54kgs. The robot can

ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

walk at the speed of 2.7 km/hr and can run at the speed of 6 km/hr in straight line. It is powered by lithium Ion 58.4V battery which takes 3 hrs to charge fully and can run for 40 min to 1hour when the robot is on continuous walk.

Basic functionality of Asimo:

Asimo is mainly designed to help and coexist in an office environment. The control system of Asimo has most of the cognitive abilities such as perception, vision, decision making, planning and learning abilities. The head is fixed with two cameras which can recognize the designated target positions through the markers. The cameras can also determine the distance and direction of the target position in the environment. Asimo uses 6-axis force sensor to measure the step size and can take a long step if required. The robot can push the cart at a preset speed. If there is an obstacle for the cart movement, the robot reduces the pushing force. The robot is capable of opening and closing the doors while passing through the door. Asimo can carry a tray with four cups and serve coffee (figure 3). Each arm can carry up to 2kg of weight. Asimo can do simple jobs, where the operation is controlled by near by laptop [7].

Fig 3 Asimo serving coffee [7]

Environment of ROBO-CAMAL architecture:

ROBO-CAMAL architecture proposed by James Gwatkin has been implemented using Amigobot [1][8]. Amigobot is a two wheeled robot with a rear stabilising tire, mounted with an array of sonar sensors. It has four sensors mounted in the front, two in rear and one on each side. The vision system of the Amigobot uses omni directional camera, which provides a 360^o of vision to the robot. The Amigobot has a capability to transfer the internal data such as the vision data and battery status through the radio modem mounted on the robot.

The robot lives in an enclosed area of two metre square with a one metre wall inside. The environment is having four objects: one blue ball, two red robots and a black robot. A black tape is glued on the lower end of the wall to distinguish between wall and the floor.

The robot uses object profiles to recognise the objects in the environment. The basic task of these robots is to avoid collision with walls and other robots, hit the blue ball in the environment.

Basic functions of ROBO-CAMAL: The Amigobot is built with intelligent control system as an artificial mind, which can make decisions on movement, while navigating in the environment. It can move in straight line with constant speed. It can sense a nearby object and turn itself to avoid the object. By sensing the far away object through its vision system, it turns itself with a constant linear speed to avoid the far object. It can detect and avoid objects very close on its sides, front and rear ends. The objects are detected either with sonar sensors or through vision system. It can identify the objects in the environment.

Fig. 4 ROBO-CAMAL environment [8]

The robot stores each object profile as knowledge, by referring to which the object is recognised. It can track the object by turning itself in the direction in which the object presents. If the object of interest is detected in the environment, it will hit the object with high speed [8].

V. PRINCIPLES OF NATURAL MIND

As we described a testbed as a tool on which the standard tasks are implemented by agents. The results of these tasks are measured and compared with animal or human behaviour. Different skills and cognitive tasks may be represented as individual micro agents. These individual micro agents will demonstrate simple, complex or intelligent behaviour, and serve to fulfil the capabilities expected of an intelligent agent, such as planning, decision making, problem solving, and

ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

learning. The purpose of this research is to understand the theory of natural minds and adopt these principles into simulations of artificial minds.

The principles of natural mind adopted in designing fungus eater testbed, described in this paper, are as follows:

- The human behaviour is consequential which depends on current state, energy use and other physiological parameters.
- The decision making in human and animal depends on cost function and utility behaviour at microeconomic levels. The cost function deals with real risks, real costs and real benefits. The utility behaviour is to maximize or minimize the utility, for example the energy, the agent at boundary condition (minimum energy required to survive in the environment) of energy tend to lookout for a source of energy.
- The law of instinct or original behaviour is that an animal in any situation, apart from learning, responds by its inherited nature
- The animal use some power of reasoning and is competent for its resources and demonstrate intelligent behaviour
- The animal mind has a limitation of not performing two tasks simultaneously, in which case it will choose potentially better task than the other by comparing some indexes.
- A person or animal makes a particular choice, when it is in the particular state; it makes the same choice when it is next in the same state if the previous visit has given optimal result.
- The rational behaviour of an agent depends on its ability in searching feasible choice in a given state, if there are no feasible choices then it chooses a preferable choice.

VI EXPERIMENTAL TESTBED SET UP

The fungus world testbed is implemented using Prolog and developed using cognitive and engineering perspectives. The fungus world environment has been created to have both dynamic and static features. The static feature can be specified to create a particular configuration of the environment. Dynamic features include the generation and use of fungus, medicine and goal resources (ore and crystal). There are different parameters in the environment for an agent's biochemical engine and performance (Table 1).

Resource parameters in the environment consist of: (1) standard fungus; (2) small fungus; (3) bad fungus; (4) ore; (5) golden ore; (6) crystal and (7) medicine**.** Fungus is a nutrient for the agents. Each standard fungus gives an agent 10 energy units. Initially, each agent has a predetermined energy level. For each cycle, the agent consumes a fixed number of energy units. If the energy level (nutrients) reaches 0, the agent will die. The small fungus gives an agent 5 energy units. If the agent consumes a small fungus, 5 energy units (default) are added to the energy storage. The bad fungus has 0 energy units. If the agent consumes bad fungus, it gets null energy. Moreover, bad fungus increases the metabolism rate, and changes the metabolism of the agent in the testbed. The collection of medicine decreases the metabolism. The metabolic effect is exactly opposite that of the collection of bad fungus

The collecting of ore is the ultimate goal of each agent. Each agent group tries to collect as much ore as possible in the environment. At the same time, an agent has to maintain the energy level necessary to live in the environment. Initially, collection is 0, and one value is added after collecting each piece of ore. Collection of golden ore increases the performance of an agent. One piece of golden ore is equal to five standard ore units. Collection of crystal increases the performance of agent by a factor that is double that of standard ore.

Experimental setup:

The environment supports the running of the various types of agents such as; reflexive, reactive, deliberative agents with learning abilities within the SMCA (Society of Mind Cognitive Architecture). Each agent uses a different type of rules and mechanisms. SMCA has many simple agents working together to exhibit intelligent behaviour. It has many simple reflexive agents to highly intelligent metacognitive agents. The agents at higher level can learn and adapt to the dynamic environments. This architecture simulated six reflexive, seven reactive, fifteen deliberative, nineteen perceptual, fifteen learning, fifteen metacontrol and seventy seven metacognition behaviours.

The reflexive agent being the simplest agent, does not exhibit any intelligence and it moves randomly in all direction, if the move is possible otherwise it moves to the edge. It can only sense the centre and edges of the environment. The reactive agent's exhibits well planned and coordinated actions to satisfy the goal specified for that agent. The reactive agents are controlled by deliberative agents. These agents always moves to the near by resource to collect as many resources as possible to achieve its goal. The reactive agent is designed with the principle of natural mind, where a human or animal is competent for its resource in the environment.

The deliberative BDI (Belief Desire and Intension) agents use required number of reactive agents and reflexive agents to meet the goal specified by the entire

ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

architecture. These agents can learn the optimal results obtained and repeat the same sequence of actions when they are in the same state next time. The agents are also having metacognitive and metacontrol capabilities [20].
The experiments were conducted with the same parameters for the presence of fungi (including standard, small, and bad), ore (including standard and golden ore) and the same objects (including obstacles). The time scale and maximum cycles were kept constant by adding the same type of agent in each experiment. 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.
The fungus world testbed is implemented using SWI-Prolog 5.4.6 (Swi-Prolog, 2003). The fungus world testbed experiments include cognitive and engineering perspectives on the architecture. The static blocks are more flexible, to create a particular location of the environment.

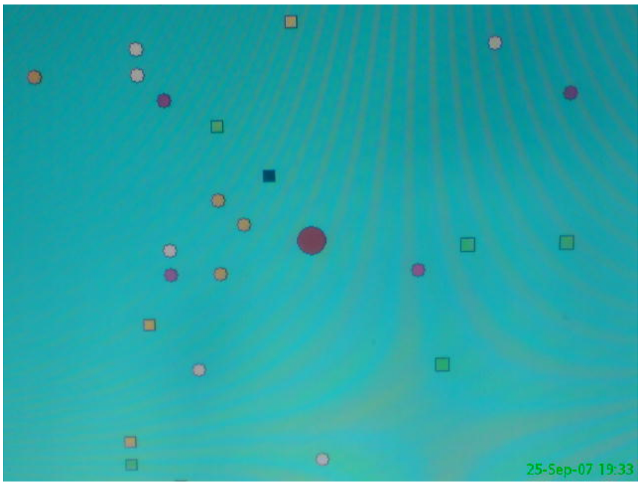

Fig 5. Fungus world Testbed

General structure of the fungus world simulation:
As shown in Figure 6, the fungus world testbed simulation may be mapped onto physically situated agents in cognitive architectures, to demonstrate "Society of Mind" [10]. Agents move and operate in an environment. At each turn, each agent performs two phases. In first phase the agent moves in an environment and checks the corresponding adjacent positions. Then the agents determine the regular (any one way) and random directions (up, down, left, and right). If the adjacent position is free, then it moves to the next corresponding location. In second phase the agents check the parameters and rules. If the rule allows it to collect, it collects the parameter or it moves based on the direction assigned. The general structure of the simulation can be sketched as follows. Initially (chosen by user), agents are randomly distributed in the environment. Each agent's initial effort is determined based on its type; for most types of agents, initial effort is determined based on their action and behaviour. Agents' position and effort may be observed on the relative display window. In every round, each agent moves randomly or in a particular direction in order to meet a fungus, ore, crystal or medicine, based on the rules and regulations framed for an each agent. An agent perceives its environment by sensing and acting rationally upon that environment with its effectors. The agent receives precepts one at a time, and maps this percept sequence into different actions.

Table 1. Parameters for fungus world environment

Parameter	Type	Value	Default Effect
Fungus	Object : Numeric	10	Increases the energy level by 10 energy units, to live in the environment
Small Fungus	Object : Numeric	5	Increases the energy level by 5 energy units, to live in the environment
Bad Fungus	Object: Numeric	0	Increases the energy level by 0 energy units, to live in the environment Decreases the performance by Increasing metabolism
Ore	Numeric	1	Increases the Performance by 1.
Golden Ore	Numeric	5	Golden Ore increases the agent performance 5 times More than an ore.
Crystal	Numeric	2	Crystal Increases the agent Performance 2 Times more than a Ore.
Medicine	Object: Numeric	0	Increases the performance by Decreasing metabolism
ENP (Energy storage)	Object: Numeric	N/A	Stores the energy based on consumption of Fungus, Small Fungus, and Bad Fungus.
Cycle	Object: categorical	1 or 2 or 5 Energy units	Agent consumes the Energy
Low Metabolism	Categorical-atom	1	Agents use energy at 1 unit per cycle
Medium Metabolism	Categorical-atom	2	Agents use energy at 2 unit per cycle
High Metabolism	Categorical-atom	5	Agents use energy at 5 unit per cycle

Dynamic agent morphology allows an ontogenetic process (metabolism) i.e., high, medium or low and aging, i.e., being born, growing, maturing aging, etc. The energy level determines the current hunger condition and thereby triggers eating (metabolism).The control architecture enables the fungus eaters to adapt to the dynamic environment. Toda [17] explains that human efficiency resides in a coordination of the different basic functions rather than each individual function.

The simulation experiments were executed several times with the same initial settings, and taking an average of ten simulation experiments generated the results.

This experiment compared the performance of agents from four levels in the SMCA architecture[18][19]. Each agent was selected from the population of agents at that level as the best (from that layer) to collect Ore. The life expectancy and ore collection for reflexive, reactive, learner and BDI agents were compared.

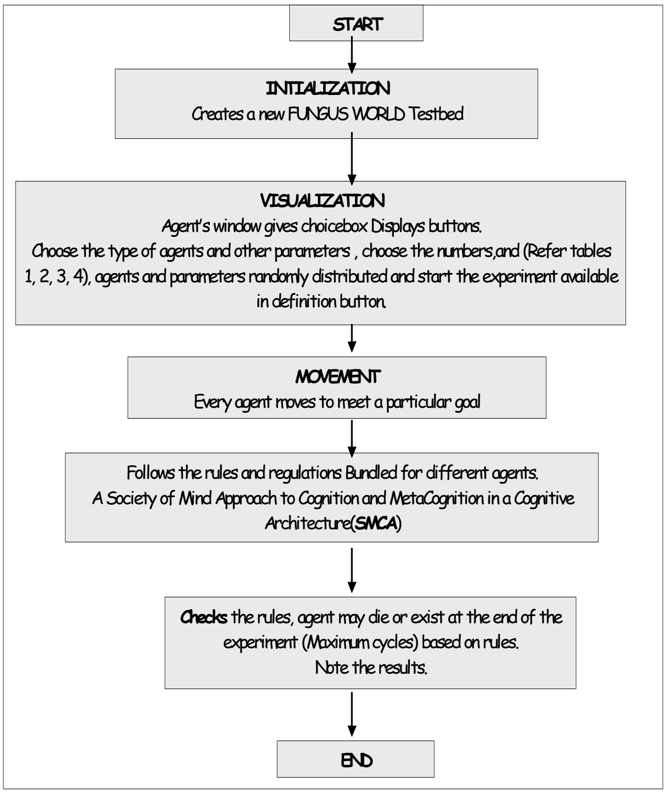

Fig 6. Simulation Flowchart (General Structure)

The results of this experiment (Fig. 7) shows that BDI model agent maintains a higher level of life expectancy than other simpler agents. Reflexive agents collected 16% of ore, while reactive agents collected 26%, simple- learning agents collected 57% and BDI agents managed to collect 80%. The BDI agents maintained a higher level of life expectancy at72.5%, than reflexive (26%), reactive (36.5%) and learning agents (41%), over the repeated experiment.

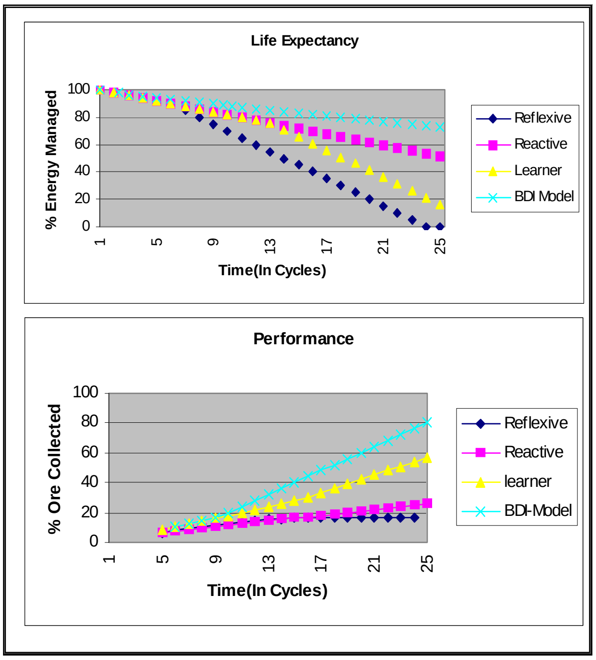

Fig 7. Performance of SMCA lower level to higher level agents

VII. CONCLUSIONS

This paper described how to set up a testbed for testing computational theories of synthetic agents and in robots.

Firstly, this paper we have described the simulated environmental setup of a synthetic robot as in Roboverse and real environments of some real time robots such as Asimo and ROBO-CAMAL.

In this paper it has been described the designing of synthetic agent's environmental setup using fungus world testbed. The experimental setup uses parameters for fungus world environment such as; replenish rates, agent performance parameters, output parameters, society of agent's setup in the experiment and general structure of the fungus world simulation.

The synthetic agents in fungus world testbed are simulated to adopt principles of natural mind in demonstrating artificial economic concepts. The agent is competent for its resources and repeating the same sequence of action in the same state, if it has achieved optimal results in its previous visit. It maintains its energy levels while executing the tasks by choosing feasible and preferable actions in every state etc,. These principles have been tested on simple to complex

ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

computational agents. It has been investigated how artificial minds can be designed for synthetic agents and robots. This research work has created a platform for demonstrating qualities of mind such as decision making, cost function, utility behaviour and goal oriented behaviour work in natural mind. Intelligent behaviour of an animal or a robot can be understood only by competition among the different types of agents by comparing their individual performances. The experiment was conducted for 500 life cycles, to find out the in-depth potential of the micro agents through their lifespan.

REFERENCES

[1] Activemedia, Amigobot technical manual, Activemedia Robotics, 2000.

[2] Anderson J, Rules of the Mind, Lawrence Erlbaum Associates, Hillsdale, NJ, 1993.

[3] Davis D N, Computational Architectures for Intelligence and Motivation, 17th IEEE International Symposium on Intelligent Control, Vancouver, Canada, 2002.

[4] Dillmann R, 2004, Benchmarks For Robotics Research, European Robotics Network, and University of Karlsrube.

[5] S. Franklin, Artificial minds, A Bradford book, MIT press, 1995.

[6] S. Hanks, M Pollack and P.R.Cohen, Benchmarks, Test-beds, Controlled, 1993.

[7] Honda Motor Co., Ltd., "Asimo Intelligent technology", available at http://world.honda.com/ASIMO/technology/intelligence.html, 2010, accessed on 28-FEB-2010

[8] James Gwatkin, "Robo-CAMAL: Anchoring in cognitive robotics" (Draft) PhD Thesis, University of Hull, March 2009, available at http://www2.dcs.hull.ac.uk/NEAT/dnd/robots/robo-camal.html

[9] Lees M, 2002, a History of the Tile world agent Testbed, School of Computer Science and Information Technology, University of Nottingham, Nottingham.

[10] M. Minsky, The society of Mind, Cofounder of the artificial intelligence, Laboratory, MIT, 1985.

[11] Newell A, Shaw J C, and Simon H A, "Empirical Explorations of the Logic Theory Machine", Proceedings of the Western Joint Computer Conference, pp. 218-239, 1957.

[12] Nason S and Laird J E, 2004, SOAR_RL integrating reinforcement learning with SOAR. Available at http://www.sciencedirect.com/science[Accessed at 20th, august, 2006].

[13] Pfeifer R, Artificial Intelligence models of emotion. In V. Hamilton, G. H. Bower & N. H. Frijda (Eds.), Cognitive perspectives of emotion and motivation (p. 287- 321). Dordrecht: Kluwer, 1988.

[14] Pfeifer R, Building " fungus eater": Design Principles of Autonomous Agents, In Proceedings of SAB 96, 1996.

[15] Marth E. Pollock, Mark Ringutte, Introducing the Tileworld: Experimentally evaluating agent architecture, In proceedings of Eighth National conference on Artificial Intelligence, available at www. Citeseerx.ist.psu.edu/viewdoc/pollack90introducing.html , 1990.

[16] Singh P, EM-ONE: Architecture for Reflective Commonsense Thinking PhD Thesis. Available at http://web.media.mit.edu/~pus , MIT, 2005.

[17] Toda M, Design of a Fungus-Eater. Behavioral Science, 7, 164-183. The Hague: Martinus Nijhoff Publishing, 1962.

[18] Venkatamuni, M. V. and Davis D. N. 'Metacognition in Society of mind', Accepted by IASTED International Conference on Artificial Intelligence and Applications, 2008 (AIA 2008), Innsbruck, Austria

[19] Venkatamuni, M. V. and Davis D. N. (2008b), 'Principles of Artificial Economics in Animal Minds', Accepted by AIPR-08, International Conference on Artificial Intelligence and Pattern Recognition, Orlando, FL, USA, July 2008.

[20] Vijayakumar M V, D.N. Davis, and K.R. Shylaja, 'Design of Metacontrol and Metacognition mechanisms in SMCA Using Norms and Affect rules' Accepted by International Conference on Artificial Intelligence and Pattern Recognition (AIPR-09), Orlando, FL, USA, July 13-16 2009

[21] Wehrle T, 1994, New fungus eater experiments. In P.Gaussier, & J.D.Nicoud (Eds.), From perception to action (pp.400-403).Los Alamitos IEEE Computer Society Press. (http://www.unige.ch/fapse/emotion/members/wehrle/fungus.htm000 [Accessed 15th April 2006]

ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)