

## Computational Testbeds For Synthetic and Robotic Agents

*Dr. M.V.Vijayakumar, Dr..Darryl. N. Davis , K.R.Shylaja, Prof.Vishwanth Y, and Dr. E.V.Prasad,*

*New Horizon College of Engineering, Bangalore, India*

*University of HULL, Hull, United Kingdom, India*

*Dr.Ambedkar Institute of Technology, Bangalore, India*

*New Horizon College of Engineering, Bangalore, India*

*JNTU, Kakinada, India*

### **Abstract**

*This paper describes how to setup frameworks for testing computational theories and robotics. Testbeds and benchmarks can be used to produce metrics for measuring and comparing the performance and outcomes in the field of robotics and cognitive architectures. Any cognitive or computational architecture can be viewed as either a single agent or a large collection of agents. Artificial Economics concepts are used to demonstrate working mechanisms in a fungus world Testbed. The metrics used in this example are associated with the principles of artificial economics and animal cognition.*

*This research aims to understand the operational settings for Robotic and simulation environments. Through this we can 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 and complex computational agents. The developed micro-agents in a fungus world are designed to investigate artificial minds for synthetic agents, drawing on qualities found in the natural (animal) 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: Test beds, fungus world, Robverse, ASIMO and ROBO-CAMAL

### **1. 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 programme (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 a performance element for 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; and are designed to be capable of performing certain behaviors and functions based on our understanding of human and nonhuman minds [5] [6] [11] [20].

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

### **2. Testbed and Benchmarks**

Testbed and benchmarks are used as environments, with synthetic agents to compare the behavior 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. 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 (Hanks, 1993). Testbed tools provide a method for data collection, ability to control environmental parameters, and scenario generation techniques.

The main purpose of a testbed is to provide metrics for evaluation in testing agents and so allow objective comparisons between agent architectures. Hanks et al. (1993) define "Benchmarks as precisely defined standardized tasks". Task means the job given for a robot to perform, and the standard means a benchmark accepted by a significant set of experts in the same field. According to Dillmann (2004), 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 on a specific problem based on a benchmark score (Dillmann, 2004). According to Hanks (1993), benchmarks are using for comparing the architectural performance on standard tasks. The results of different architectures can be compared and measured, across a range of standard tasks. Artificial intelligence contains standard tasks for AI problems.

### 3. Simulation Testbeds

Some of the test beds used for testing the performance of simulated synthetic agents are been discussed below.

An important issue in developing testbeds 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 (Nason and Laird, 2004), Tile world (Pollack and Ringuette, 1990), and fungus world (Toda, 1986)

#### 3.1 Packman

SOAR 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 an empty cell in the environment or grid board. The agent's capabilities are tested by giving different skills including reinforcement learning. (Nason and Laird, 2004).

#### 3.2 Tile World

Pollack and Ringuette initially introduced the tile world testbed in 1990. Tile world is a highly parameterized environment, and this can be used to investigate reasoning an agent (Lees, 2002). The tile world is an abstract testbed designed for experimenting with multi agent architectures in dynamic and unpredictable environments.

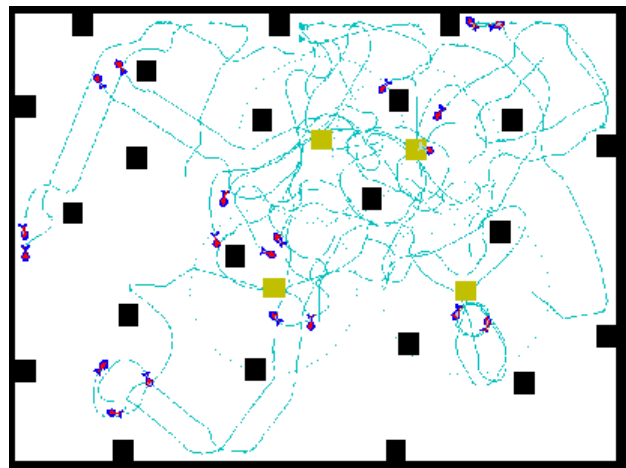
Tile world is a two dimensional grid on which located different kinds of objects or environment parameters. The parameters are tiles, holes, obstacles and a gas station or energy source. Once the simulation is running, an object be configured to appear and disappear. The environment parameters can be controlled with variety of characteristics associated with the objects. The original tile world consists of a grid cells (squares) on which different objects can exist. An agent can move up, down,

left and right. The goal of the agent is to collect tiles and move them in order 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 as possible. Tile world simulations are dynamic, and the environment can change continuously (Lees,2002).

#### 3.3 Fungus world

Toda (1961) compared a "complete system" with a microcosm environment. The fungus eater is a simulated robot used for fictitious mining. It has been 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 are usually not found in the same place. They will be kept a certain distance from each other in order to avoid collision (Wehrle, 1994, Lewis, 2004).

Fungus eaters are synthetic artificial agents and a particular species of animats. Animats can be productively viewed from a designer perspective. Masanao and Toda (1961) invented a new fungus eater testbed, for simulating artificial synthetic agents. Multiple agents can present in the environment at the same time. Pfeiffer (1994) assumes: (1) movement or locomotion using legs, (2) collection or consumption using arms and (3) decision making using a brain.



*Fig 1. Toda's Simulator test bed*

As shown in figure 1 Toda (1986) proposed the use of a micro world (a micro cosmos) for the purpose of modelling mechanisms and for collecting empirical data (Wehrle, 1994). The animats approach plays an important role in the design and experimentation on computational intelligence and cognition. The fungus world environment and working principles allow a robot or any artificial mind a requirement for exhibiting a specific behaviour in a

specific environment. Pfeifer (1988, 1994) 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 (Pfeifer, 1994).

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 (Pfeifer, 1994).

#### 4. 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 may be dynamic where the agent may encounter an unexpected obstacle or object in its environment. The objects in the real world or 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.

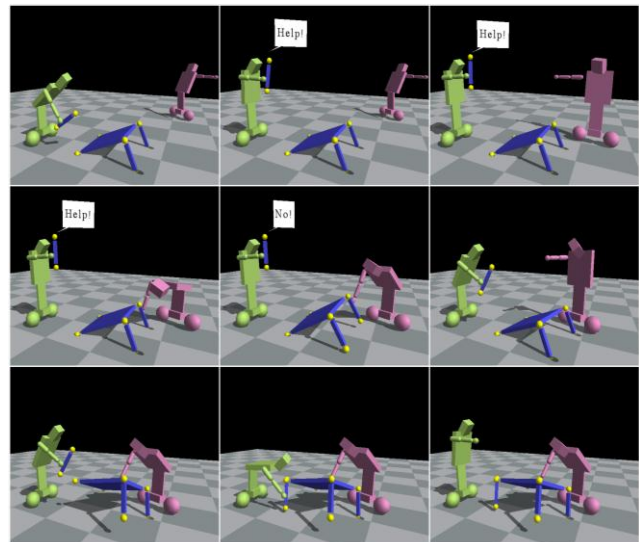
##### 4.1 Roboverse Testbed for EM-One architecture

EM-ONE architecture originated from Marvin Minsky's "emotion machine" architecture (Singh, 2005). EM-ONE architecture was proposed by Minsky and his student Singh (2005), from MIT media lab. The EM-ONE architecture (for commonsense computing) 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. EM1 uses a static environment for table building. This is an artificial environment populated with actors of rigid body physics.

These actors work together to build tables and chairs, by using simple and modular components like sticks and boards. Components look like small toys, and they can attach one other with their corner and endpoints. The actors are simulated robots, and possess a perceptual system coupled with (virtual) physical actions. They are roughly human shaped, with a single arm. The hands can be turned off and on. These hands will act like magnets by

attracting the nearer objects. Singh demonstrated the commonsense mechanism, using as an illustration, the building a table (Figure 2) in Roboverse.

The Roboverse environment has robot like 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. The sticks can attach to the corners of other sticks or the table corners. The robot has single hand and can perform only one job at a time. It can also interact with the pink robot to take help in building the table.



**Fig 2. Singh's Table Building Mechanisms(singh,2005)**

In Figure 2, Green (left side) wants to build a table; Green determines if there are any partly built tables to attach more legs to complete building a table. Green moves and grabs a stick, and then moves nearest to the incomplete table (figure centre). Green tries to build a table by using its single arm. It tries to match and attach the table legs, but it fails. Green immediately realizes it needs help., Green calls the Pink. Until then, Pink has been involved with its own project, and has not been paying attention towards Green. The Pink looks over to Green, and (mistakenly) realizes Green is trying to disassemble the partially built table. Pink comes nearer, and removes the one of the table leg. Green realizes Pink does not understand the intention of Green, and then complains. Green realizes Pink, did not see Green attaching a stick. Afterwards, Green again tries to attach a stick to the partly built table. This time, the Pink watches the construction. Pink realizes that the Green's intention is to complete a table, rather disassemble the table. Green expects help from the Pink. Green expects Pink to hold a table, so that Green can attach a table leg. Pink holds a table and Green inserts the stick. This mechanism proposes a course of action and intentions of other actors for reflecting upon

repairing mistaken errors. It shows aspects of physical, social, and mental actions.

## 4.2 ASIMO Robotic Testbed

Asimo is a more advanced humanoid robot that looks like an astronaut with a backpack. The robot is designed mainly to help and live in harmony within 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 (Honda, 2010).

Asimo has 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 comfortable working in human operating environment. Asimo's height is 130cm and its weight is 54kgs. The robot can 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.



*Fig 3 Asimo serving coffee (Honda, 2010)*

**Basic functionality of Asimo:** Asimo is mainly designed to help and coexist in an office environment. The head is fixed with two cameras which can recognize the designated target positions through the use of 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 a 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 through a nearby laptop.

## 4.3 Environment used in ROBO\_CAMAL

The ROBO\_CAMAL architecture proposed by Gwatkin (2009) has been implemented using an Amigobot (Active Media, 2000). 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 ROBO\_CAMAL Amigobot uses an omni-directional camera, which provides a 360° field of vision to the robot. The Amigobot has a capability to transfer its internal camera, sonar and battery status data through the radio modem mounted on the robot. The robot uses object profiles to recognize the objects in the environment.

The robot lives in an enclosed area of two meter square with a one meter wall inside (Figure 4). The environment can contain four objects: one blue ball, two red robots and a black robot. Black tape is glued on the lower end of the wall to distinguish between wall and the floor.



*Fig. 4 ROBO\_CAMAL environment (Gwatkin, 2009)*

### **Basic functions of ROBO\_CAMAL:**

The basic task of these robots is a subset of Robotic football tasks such as to avoid collision with walls and other robots and hit the blue ball.

The Amigobot can move in straight line with constant speed. 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 sense a nearby object and turn itself to avoid the object. By sensing a far away object through its vision system, it turns itself with a constant linear speed to avoid the far object. It can identify the objects in the environment. The robot stores each object profile as knowledge, by referring to which the object is recognized. It can track a dynamic object by turning itself in the direction of the object.

## 5. SMCA Experimental Testbed Setup

A 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). These different parameters of the environment are related to the agent's biochemical engine (Table 1).

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

**Table 1. Parameters for fungus world environment.**

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 testbed cycle, the agent consumes a fixed number of energy units. If the energy level (nutrients) reaches 0, the agent will die. 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 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 from 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 for 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.

The environment supports the running of the various types of agents within the SMCA architecture (Venkatamuni and Davis, 2008), where each agent uses different types of rules and mechanisms. In these experiments, a maximum of 50 agents were defined. 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 static blocks (or 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.

### 5.1 General structure of the fungus world simulation

As shown in Figure 5, the fungus world testbed simulation can be mapped onto physically situated agents in cognitive architectures, to demonstrate "Society of Mind". Agents move and operate in an environment. At each turn, each agent performs two phases. First, the agent moves in an environment and checks the corresponding adjacent positions.

Agents determine the regular (any one way) and random directions (up, down, left, and right). If the adjacent position is space free, then it moves to the next corresponding location. Secondly, agents check the parameters and rules. If the rule allows it to collect, it collects the environment parameter, or moves, based on the direction assigned. The general structure of the simulation can be sketched as follows. Initially, agents (chosen by user) 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.

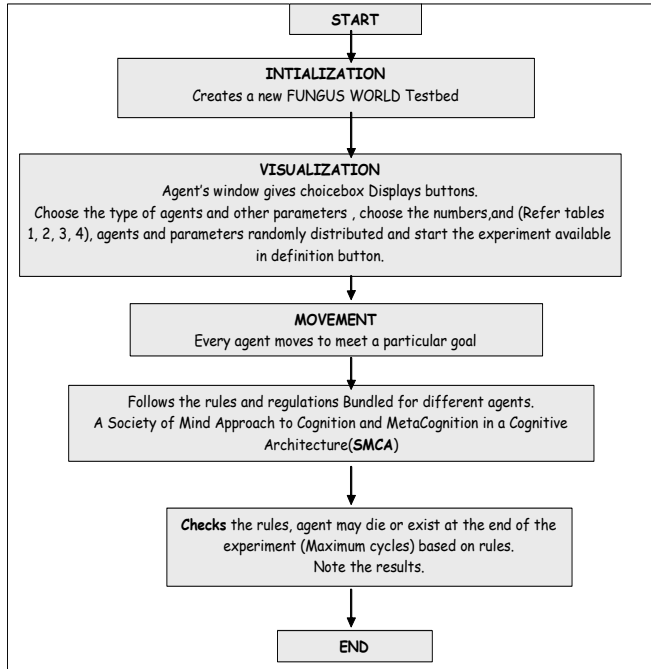


Fig 5 . Simulation Flowchart (General Structure)

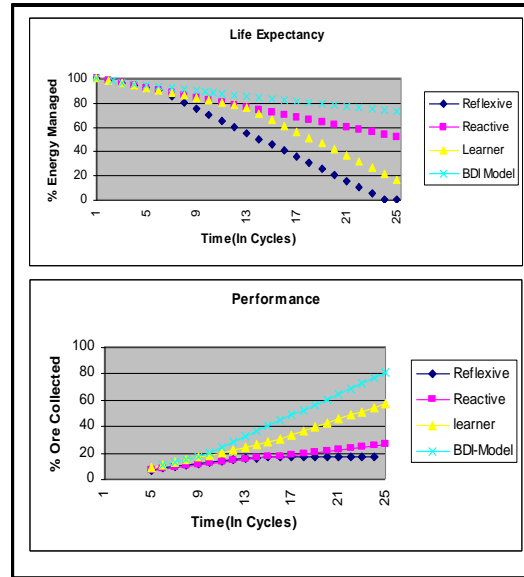
Dynamic agent morphology allows an ontogenetic process (metabolism) i.e., high, medium or low and aging, i.e., being born, growing, maturing aging, etc. The energy level determines the current hunger condition and thereby triggers eating (metabolism). The control architecture enables the fungus eaters to adapt to the dynamic environment. Toda (1976) 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 the result graphs were generated by taking an average of ten simulation experiments.

### Experimental Setup

This experiment compared the performance of agents from four levels in the SMCA architecture. 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.



Graph 1. Performance of SMCA lower level to higher level agents

The results of this experiment (Graph 1) 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 at 72.5%, than reflexive (26%), reactive (36.5%) and learning agents (41%), over the repeated experiment.

### 6. Conclusions

This paper described the design of the fungus world testbed and development undertaken enabling experimental setup. It has given the experimental setup with parameters for fungus world environment, replenish rates, agent performance parameters, output parameters, society of agent's setup in the experiment and general structure of the fungus world simulation. Intelligent behaviour of an animal or a robot can be only understood 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.

### 7. References

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

- Baars B J, *A Cognitive Theory of Consciousness*. New York: Cambridge University Press, 1988.
- Bedau M A, *Artificial life: Organization, Adaptation, and Complexity From the Bottom Up, Trends In Cognitive Science*, Volume 7, Issue 11, 2003, Pages 505-512, [Online] Available at [www.sciencedirect.com](http://www.sciencedirect.com).
- Darwin C, *Expression of The Emotions in Man and Animals*, 1872, Paul Ekman (Ed), Oxford, 1998, ISBN 0195112717.
- Davis D N, *Computational Architectures for Intelligence and Motivation*, *17th IEEE International Symposium on Intelligent Control*, Vancouver, Canada, 2002.
- S. Franklin, *Artificial minds*, A Bradford book, MIT press, 1995.
- Franklin S, *Autonomous Agents as Embodied AI Cybernetics and Systems*, 28:6, 499-520, 1997.
- S. Hanks, M Pollack and P.R.Cohen, *Benchmarks, Test-beds, Controlled*, 1993.
- D. McFarland, T. Bossler, *Intelligent behavior in animals and robots*, MIT press, Massachusetts, 1993.
- M. Minsky, *The society of Mind*, MIT, 1985.
- 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.
- Newell A and Simon H, *Human Problem Solving*. Englewood Cliffs, NJ: Prentice-Hall, 1972.
- 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.
- Pfeifer R**, 1994, "The fungus eaters Approach" to emotion a view from artificial intelligence, AI Lab Institute for Informatics. University of Zurich-Irchel, Switzerland.
- Selfridge O, 1959, *Pandemonium: A paradigm for learning*. In *Symposium on the mechanization of thought processes*.
- Singh P, *EM-ONE: Architecture for Reflective Commonsense Thinking* PhD Thesis. Available at <http://web.media.mit.edu/~pus> , MIT, 2005.
- Sloman A, *How To think About Cognitive Systems: Requirements And Design*, Available at <http://www.cs.bham.ac.uk/research/cogaff/>, 2002,
- Stillings N, *Cognitive Science*. Second edition. Cambridge, MA: MIT Press, 1995.
- Thorndike, E. L, *Animal intelligence: Experimental studies*. New York: Macmillan, 1911
- Toda M, *Design of a Fungus-Eater*. *Behavioral Science*, 7, 164-183. The Hague: Martinus Nijhoff Publishing, 1962.
- 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
- 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.
- 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>
- Honda Motor Co., Ltd., "Asimo Intelligent technology ", available at <http://world.honda.com/ASIMO/technology/intelligence.html>, 2010, accessed on 28-FEB-2010