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# COMPARISON OF DIFFERENT COGNITIVE ARCHITECTURES WITH THE NEWLY PROPOSED CSIA ARCHITECTURE

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**Abstract :** This paper focus on various Cognitive architectures. These architectures are designed which helps us to understand the basic aspects of cognition. They show the various components involved in it and their flow of control. Cognitive architecture gives us the working model for the various cognitive phenomena. Here we also discuss about the proposed architecture where CST is implemented in Meta thinking layer and by this it could be possible for faster skill acquisition and those skills can be used to solve another problem later.

***Keywords: Belief, Cognition, Desire, Perception.***

## I. INTRODUCTION

A cognitive architecture is about details of structure of the human mind. The main aim of a cognitive architecture is to provide the entire insight of the various outcomes of cognitive psychology in a comprehensive computer model. There are various cognitive architectures available but here we focus on SMCA (Vijayakumar, 2008), CRIBB (Bartsch and Wellman, 1989), EM-ONE (Singh, 2005).BDI (Michael Bratman,1980),SACA (Ashwini k,2016) and newly proposed CSIA architecture. CRIBB is about reasoning in young children. Common sense computing and the communication by the EM-ONE. SMCA demonstrates the Controlling mechanism of the mind. BDI is an architecture which explains about belief, desire and intension. SACA architecture describes the collective behavior of simple and intelligent swarm agents.

## II. CRIBB ARCHITECTURE

Cognitive science is the study of cognition and intelligence. The word cognition attributes about the mental actions taken during different situations, cognition includes investigation in various mental states like reasoning, thinking, belief, desire,emotions etc. which would provide us knowledge in fields like psychology, philosophy in order to build an effective cognitive architectures. Conceptual state produces the reasons and clarification or individual's activities and observations, but it is non-materialist. Cognitive architecture are designed in order to understand the basic aspects of cognition. They show the various components involved in it and their flow of control. Cognitive architectures provide the working model for the various cognitive phenomena [1]. A number of scientists including Wimmer, Perner, Wahl, and Spada conducted a sequence of demonstrations were made to investigate if young one of age between 3 to 5 is having the characteristic of faulty belief to others. The result proved that the children's whose age is 5 is not having any issues in characterizing the faulty belief. The capability to recognize faulty-belief objective confirmed that when the individual value the differentiation among mind and the world[2]. Lots of investigation is made on the hypothesis of mind is anxious about faulty belief among 3 to 5 age of children's, their part in forecasting or clarification of conduct and tries to change conduct. CRIBB (Children's Reasoning about Intentions, Beliefs, and Behaviour) depends on Belief-Desire reasoning [3] proposed by Bartsch and Wellman's and stimulates understanding and assumption procedure of capable child resolving problems and faulty-view goals [1].

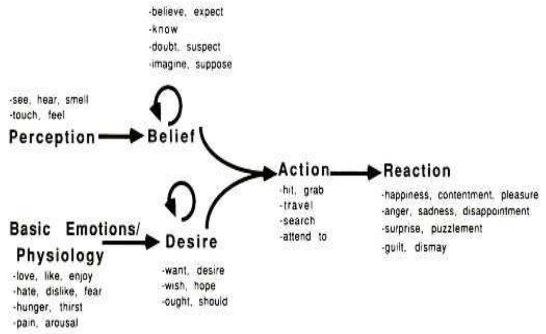


Figure 1: belief-desire reasoning scheme.

The belief desire reasoning scheme is shown in Fig.1 the inputs to the model are perception, basic emotions, and physiology. The agent's beliefs are determined by its perception of the environment and its formerly-based belief. The individual's passions are determined by its basic emotions, physiology, and its previously-held desires. Belief is the way of representing the state of environment and desire is the representation of the end state. Both belief and desire put together shows action or plans. These can lead to reactions that may consequently change the individual's environment and possibly the individual's emotional condition and physiology. On the process of achieving the goal or performing a task is to perform the action based on the beliefs the agent has at that time.

Unfortunately if the environment changes the agent's belief are modified accordingly. This means the previous action is no longer valid. As the action has no access to the new beliefs, it will still act and may fail to achieve its goals, for this reasons intentions are also required. These concepts help to build the CRIBB architecture. The CRIBB architecture is shown in the Fig.2.

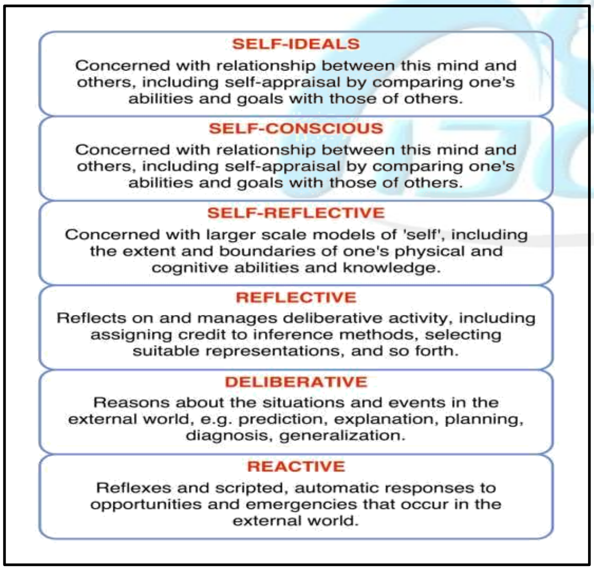


Figure 2: CRIBB architecture

The CRIBB architecture mainly consists of two representations. They are primary representation and secondary representation.

- Primary representations provides information about the agent's simulated environment. They are the structure of particular opinion regarding a condition and conduct of person and other facts about physical world.
- Secondary representations describes about the agent's state. The different mental states included are like perception, belief and intentions. This model states that a person's actions can be explained by his belief and desires, where opinion can be taken from realization and formerly-based belief [4].

The architecture also encloses various inference schemas.

- *Perception-belief inference*- provides insight about the relationship between perceptions and beliefs. If the agent perceives Xthen agent believes X.
- *Fact-time and belief-time* inferences deal with facts and beliefs along a time line [3].

A practical syllogism represents the relation between the intention, belief and desire.

There are four practical syllogisms implemented.

- The first is to predict the behaviour of agents, if an agent has particular desire and it finds that some specific action would help to achieve its desire then it performs that particular action.
- The second infers the intention of an agent based on its behaviour and belief.
- The third provides knowledge about the agent's belief from its intentions and behaviour under the situation.
- The fourth is the application of the first practical syllogism to another agents.

## III. EM-ONE ARCHITECTURE

EM-ONE is a kind of cognitive programming language it provides an architecture for common sense thinking capable of reflective, reasoning about situations which involves physical, social and mental dimensions [5]. All the dimensions defining situations uses the knowledge based on a library of common sense narratives. These describes the dimensions that occur during an interaction between several actors, it reasons with these narratives by applying mental critics [5]. It is developed and tested under artificial life domain in which the simulated robotic actors face concrete physical and social problem. The common sense factor is implemented as same as the human common sense thinking, as it is a richer phenomenon than any of the automated reasoning process that are familiar in AI[6]. Common sense is implemented on AI because it should be capable of thinking in multiple, rich ways about each of the realms provided. Purpose:

EM-ONE is designed to support the kind of common sense thinking required to produce the scenario described. EM-ONE proposal is based on critic-selector model [6], it gives the explanation about the problem thinking, it provides the system the way to face the problem, it implies the general immunity and it stimulates AI in what way to encounter the problem. The top level of its proposal is meta managerial critics (meta data) [6] it explains about inside and outside problems i.e. based on the critics identify the problem. These Meta managerial critics describes the six layer model,

provides common sense thinking. The model explains about the six different layers 1. Reactive, 2. Deliberative,
3. Reflective, 4. Self-reflective, 5. Self-conscious
6. Self-ideals. The six layers of EM-ONE is shown in Fig.3.

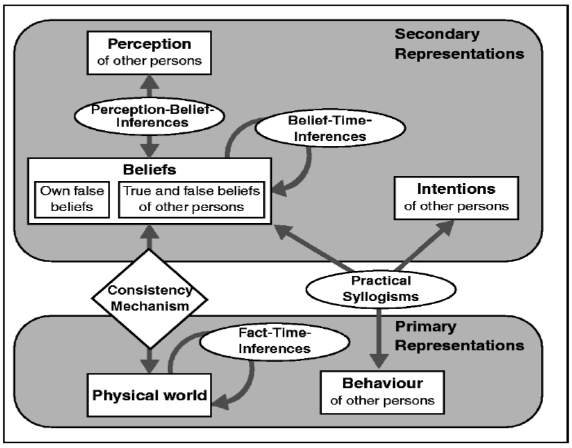


Figure 3: six layers of EM-ONE

Explanation Mental Critics: These are implemented as pattern matching procedures that solve the problem by case based reasoning using a library narrative cases. These are not only involved in identifying the problem but these also provide the solutions to it. Critics recognize the problem by matching patterns encoded in a frame-based knowledge representation language that supports the description of structured scenario involving many concerned actors, actions, situations, events, objects and properties, including mental relation such as observer, belief and desires. The frame based knowledge gives the explanation about the behaviour, considering the objects, looking in same direction, moving, turning, reacting at other side. Example: (start-behaviour (grasps: actor pink: object stick 1)) [5].In this example it initiates the action of grasping stick. EM-ONE includes the sensoreffector interface to control the activity of the robots in the elemental world. Frames explain about the helpfulness and hindrance, nearness of objects
[5]. Common Sense Narrator Em-One acts on common sense library, as Meta critics doesn't have any many ideas, it needs help. Mental critics draw from the narrative corpus for ideas about how to act, deliberate and reflect on physical (effect of attacking two body), social (actors often knows what it desires), mental (they may infer the reason for taking the action) [5]. Making the system intelligent EM-ONE is built on top of critic-L, a common lisp based reflective rule based evaluator for mental critics [7]. The cognitive cycle, evaluator accepts observation about the external environment and then runs on all available meta critics. The explanation about the emotions and the reaction to be provided is given by emotion machine [7].

### 3.1 Drawbacks

1. EM-ONE is incomplete as many of the ideas were supposed to be built on EM-TWO by the author.
2. There are many critics left uncovered, as their domain may be changed irrespective of physical, social and mental.
3. In this critic only match of particular knowledge is explained but analogy making should be implemented.
4. Extension of narrative corpus has to be done, as there exists different kinds of problems
5. Unifyingof critics and narratives should have been done.
6. Extension of EM-ONE, so that Meta management engages narrative case to decide the styles of think.

## IV. BDI ARCHITECTURE

The BDI (beliefs, desires and intentions) models was developed by Michael Bratman, the principles of architecture was developed in mid-1980's[8]. It is a software model developed for programming intelligent agents. This model is to solve a particular problem in agent programming by considering the implementation of agents's beliefs,desiers and intentions. The metacontrol and metacognition mechanisms are used in controlling the BDI models that belongs to the top level of architecture. The BDI models are developed to exhibit the way metacontrol and metacognition, mechanisms can be applied within various models (thinking of energy, thinking of metabolism, thinking of their goals, according to their self-reflection or internal conditions).[4] BDI architecture belong to the deliberative level of the architecture.

Deliberative agents compromise the third layer of the Society of Mind Cognitive Architecture In the deliberate level, agent generates a set of Possible alternatives and agent chooses between competing alternatives, and commits to achieving them. Deliberative or BDI (Belief-Desire-Intention) agents are built on the behaviours used in the reflexive and reactive agents. The actions of deliberative are designed and coordinate by considering agent, about its internal state, its motivations and agent's perception of resources in the environment [4]. BDI systems choose to satisfice rather than optimize in order to ensure that they are not overwhelmed with planning [11]. In the first step, deliberation(of goals), A set of desires is selected and is achieved based on agents belief in the current situation, The second step is responsible for providing the practical exhibition of how these concrete goals produced as a result of previous step can be achieved by the means of available options for the agent [14].

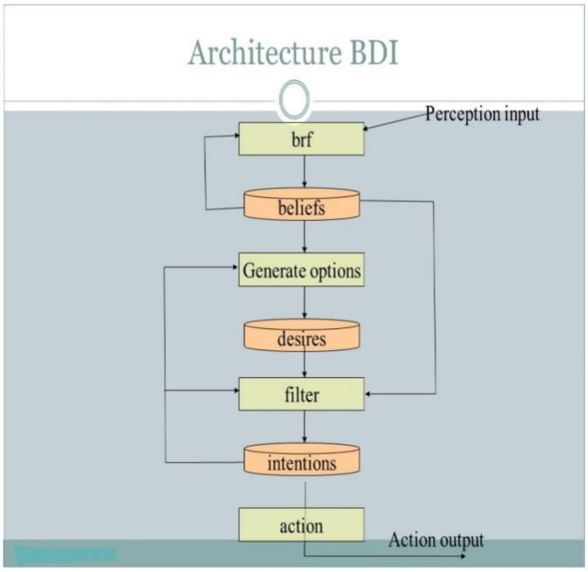


**Figure 4: BDI-architecture**

Explanation of BDI architecture which is shown in Figure.4.

- Perception input--anything that comes from the environment: stimuli or messages from other agents.
- Belief revision function—Here the new set of beliefs are determined by taking perceptual input and the agent's current beliefs.
- Beliefs -- information with respect to the world that the agent contains. Using the term belief rather than knowledge, we can recognize that what an agent believes may not necessarily be true.

Beliefs represent the local information of agents about both the environment and its internal state.

- Belief set: Beliefs are stored in database. (This may also be called as belief base or a belief set), even if it is an implementation decision.
- Generated options-- alternatives to accomplish the desires and which are generated based on current beliefs and intentions.
- Desires -- states of affairs that the agent, in an ideal world, would wish to be brought about. This is a motivation stage of agent.

Goals: Is about what the agent has decided to attempt and achieve.The goals which reactive level attempt to satisfy as those specified by the deliberative BDI agent

- Filter function-- which represents the agent's deliberation process, and which finds the agent's intentions on the basis of its current beliefs, desires, and intentions;
- Intentions –The desires that the agent has committed to achieve.

Plans: the planning process involves repetitively selecting and applying an applicable reduction method to achieve the goal.

Events: Event is an internal/external trigger that an agent receives or perceives and will react to. An event may update beliefs, trigger plans or modify goals.

**4.1 Drawbacks**

Learning: A BDI agent does not learn from past behaviour and also does not adapt to new situations. [9][10]

Logics: The multi-modal logics that underlie BDI (that do not have complete axiomatizations and are not efficiently computable) have little relevance in practice.

Three Attitude: whether the three attitudes are sufficient. [8]

Multiple Agents: In addition to not explicitly supporting learning, the framework may not be suitable to learning behaviour. Further, the BDI model does not explicitly provide information about the mechanisms for interaction with other agents and integration into a multi-agent system. [11]

Explicit Goals: The explicit representation of goals are not present in most of BDI implementations. [12]

Look ahead: The BDI architecture from the design does not have any look ahead deliberation or forward planning. This may not be very much adoptable because adopted plans may use up limited resources, reversing the actions may not be possible, the execution of task may take longer when compared to forward planning, and actions may have undesirable side effects if unsuccessful actions may have undesirable side effects.[13]

## V. SMCA ARCHITECTURE

The developing Society of Mind Cognitive architecture extends the CAMAL cognitive architecture with extra processing layers using the society of mind and metacognition concepts. Simple behaviours are combined together to form an intelligent behaviour. In this architecture mind is represented as "collection of agents". SMCA architecture is implemented as 6-layered architecture. .The six layers are reflexive, reactive, deliberative(including all BDI MODELS), learning (q-learner), meta-control and metacognition. The architecture has six reflexive behaviours, eight reactive behaviours, fifteen deliberative behaviours, nineteen perceptual behaviours, fifteen learning behaviours, thirty metacontrol behaviours and seventy-seven metacognition behaviours. Each behaviour is modelled as an agent. The Figure 5 shows SMCA architecture.

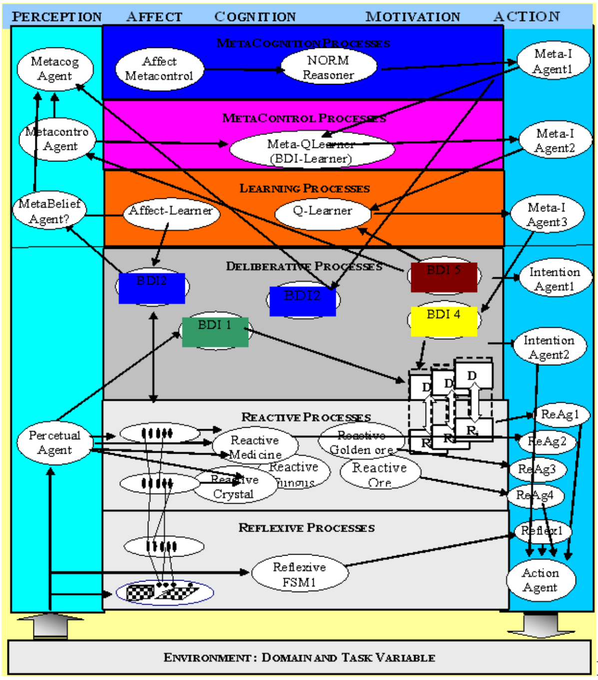


Figure 5:SMCA architecture.

Reflexive Level: It is the first level in SMCA architecture, where the agents will shows the simplebehaviours. The output is produced based on the input given. The agents will act accordingly based on what the input is (i.e., perception).Behavioural response such as an action will be the output. Reflexive agents will follow the environmental rules. The reflexive level exhibits simple reflexes such as avoid hitting the wall, avoid obstacles.

Reactive Level: In the reflexive level the output will always be the same for the same input. In reactive level the output is obtained considering its input, and also considering its internal state. Reactive agentsexhibit goal oriented behaviour.

Deliberative Level: Deliberative refers to any system whose output is determined by its input and current state, and in addition considering itsprevious states and/or the current/previous states of other systems. Deliberate agents occupy the third layer of SMCA architecture.

Learning Level: Learning is all about decision making at one level based on the actions at another level. The current implementation makes use reinforcement learning .Q-learning is implemented in this layer.This learning attempts to improve the effectiveness of the planning. The learning mechanism can follow according to rules framed in the deliberative, metacontrol and metacognition levels.

Metacontrol Level: Metacontrol agents will decide which deliberative agents are to be learnt.

The metacontol agent performs the following tasks:

1. when to learn

2. what to learn

3. what decision has to be made.

Metacognition Level: This is the final level of SMCA architecture. This is also called ad self-regulating level. It monitors the thinking process of agents.By knowing the details we can say that, SMCA architecture is based on sense-decide-act principle.

## VI. SACA Architecture (Swarm Ambient Cognitive Architecture)

SACA architecture is developed by Ashwini k. (2016). It consist of 4 layers-reflexive-reactive, deliberative, swarm, and meta-learning layer. The layered SACA architecture is shown in the Figure 6.

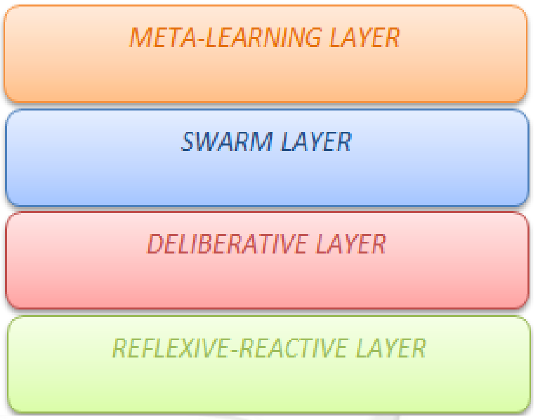


**Figure 6: Layered SACA architecture**

The SACA architecture explains the collective behaviour of simple and intelligent swarm agents. The agent uses cognition to metacognition in the process to show the intelligent behaviour.

SACA architecture has reflexive, reactive, deliberative, swarm, and meta-learning agents. The reflexive agent which is in reflexive layer will exhibit the reflexive behaviour of action by taking into considerations the environmentalconditions. The reactive agent at the reactive layer shows the goal oriented behaviour. The agent at this layer is concentrating mainly on the goals and hence shows reactive actions such as shortest route, coordinated actions that takes place between agent and parameters in the environment. The deliberative agent which is located in deliberative layers are more constantly aiming to have control over its internal state and it is highly focused to reach the goal. The BDI model is associated to the deliberative level of the architecture. At the swarm layer, the agents work together through proper coordination and communication and thereby increase the performance. Meta learning agent is used to decide when the agent has to be learned. The top level of SACA is Meta learning, which exhibits the mechanism that is used for controlling the BDI models belong to the top level of the SACA architecture.

Reflexive layer
These agents are in lower level and exhibit simple reflexive behaviour, the actions which happen before thinking. These agents exhibit low level of motivation or same times zero level of motivation towards the collection of goal parameters.
Reactive layer
These agents showcase acceptable and interrelate operations to fulfil the objective described for the agent. The reactive agent is highly goal oriented and the reactive agent's actions are controlled by the deliberative agent. Hence the agent exhibit extrinsic motivation.
These agents lack in intrinsic motivation such as understanding that its energy level has gone down below the threshold and it requires food to survive longer in the environment.
Deliberative layer
BDI agent is in the deliberative level which is at second layer in the architecture. Deliberative agent is very efficient in intellectualize regarding their personal inner function and procedures. It is highly focused towards the goal. Since this agent can reason about their own internal task and plan, this agent shows intrinsic type of motivation towards the goal.
Swarm Layer
This is the layer where all three reflexive, reactive and deliberative agents are considered. Together all the agents are called swarm agents.At this layer the agents will communicate through proper coordination and perform the assigned task.

## VII.PROPOSED ARCHITECTURE-CSIA ARCHITECTURE

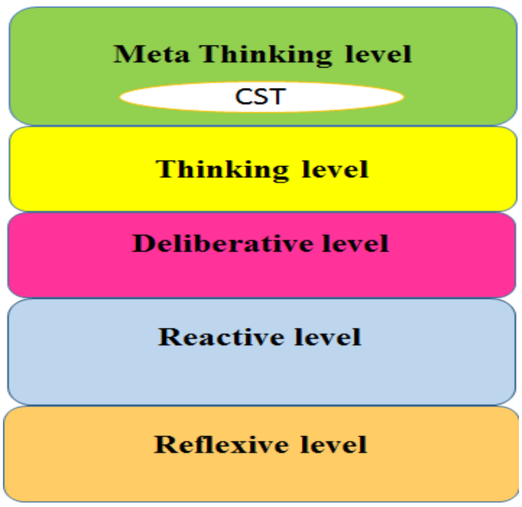


Figure 7. CSIA architecture

The CSIA architecture is shown in Figure 7.Proposed architecture is CSIA, The architecture consists of 5 layers: Reflexive, Reactive,Deliberative, Thinking and Metathinking.

**Reflexive Level:**

- It is the first level where the agents exhibit the simplest behaviours.
- The reflexive level exhibits simple reflexes such as avoid hitting the wall, avoid obstacles.

**Reactive Level:**

- Reactive agent will react once it has consumed the food. This reaction is shown by the energy parameter of the agents. Reactive agents exhibit goal oriented behaviour.

**Deliberative Level:**

- Deliberative refers to any agent capable of making decisions.
- Deliberative agents occupy the third level of CSIA architecture.
- This layer is involved in decision making.

**Thinking Level:**

- The agents will make decisions at one level, based on the actions that occurred at another level.
- This learning improves the effectiveness and efficiency of the architecture.
- The actions for agents are to be experimented by trial and error method.

**Meta Thinking level:**

- Meta-thinking refers to thinking on thinking.
- The learning ability of the agents in the thinking level is improved over time. Actions that are learnt in thinking level will be captured as sub-skills so that, they are used for future conditions.
- The agents in meta-thinking level communicate with the other agents. In meta thinking CST is been implemented which will help in faster skill acquisition.

## VIII. CONCLUSION

CST is Construction skill tree where the demonstration trajectory is segmented into skill, which has specific goal.CST helps in successfully segmenting trajectories demonstrated and assign relevant abstractions to each individual skill. The robots will be able to use the skills acquired in some problem to more quickly solve a new problem. This helps in faster skill acquisitions which helps us to distinguish between ripe and unripe fruits. By CST we can overcome the disadvantage of existing fruit picking robots.

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