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A Comparative Analysis of Cognitive Architecture

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Abstract— **In this paper, we discussing about a theoretical comparison among five of the most popular cognitive architectures: ACT-R, SOAR, LIDA, CLARION and EPIC. These architectures are compared based on a set of cognitive architecture criteria, and how the each architecture deals with them. The comparison emphasizes similarities and differences among the architectures, with the purpose to advise a required user how to identify the best architecture to choose, depending on the situation. The purpose of this paper is to compare between a set of cognitive architecture where we conduct a detailed functional comparison underlying the wide range of cognitive components, including perception, goal representation, memory types, learning mechanism and problem-solving method. This comparative study aims to determine the most appropriate architecture for our users depending on the different situation.**

Keywords— **Cognitive Science, Cognitive Architecture, Comparative criteria, Challenges**

I. Introduction

The cognitive science is a scientific study of interdisciplinary approaches of thinking, learning, and mental organization, that designing an aspects of psychology, linguistics, philosophy, and computer cognitive modelling. Cognitive Science is a study about mind and its behaviour based on the various differences. Cognitive Science involving of multiple research disciplines and which includes psychology, artificial intelligence, philosophy, neuroscience, linguistics, and anthropology.

A cognitive architecture is design to create artificial intelligent agent and proposes a computational process like human. In this, the approaches for model the behavioural as well as structural properties of cognitive modelled system.

II. Cognitive Architecture

A. *What is Cognitive Architecture?*

A cognitive architecture (Samsonovich 2010) is a designing of infrastructure for a computational system particularly for simulating or modelling of human cognition. In earlier stage, there are number of cognitive architectures have been proposed, implemented, and finally compared with human performance.

A cognitive architecture (Newell 1990, Sun 2002) is an extremely-scoped generic domain computational cognition model, collecting the required structure and process of mind to be used for large area, multilevel, various domain of behavioural analysis.

The Conceptual Structures (Sowa 1984) analysed the level of the position in the early 1980s and proposed a design that has modelled a wide range of research and development projects. After a number of years, it's time to survey the progress in the aspect of current developments in cognitive science, artificial intelligence, and computational linguistics. To provide information, it's useful to study report of some related architectures that have also been under development for a various environments.

This study used to explore this notion of architecture with an analysis. The architecture for a building consists of its overall framework and its full design, roofs, foundations, walls, windows, floors, mind structure and neural. User required appliances can be easily replaced and so that are not part of the architecture. A cognitive architecture contains full view of structures, required divisions of modules, essential relations between modules, basic representations and algorithms presents in the modules, and several of other aspects (Sun 2004). In generic domain architecture contain that concentration of a system that is invariant across time, domains, and individuals. It deals with componential processes of cognition in a structurally well defined.

In this study to understanding the human mind (i.e., cognitive science), a cognitive architecture provides a strong framework for informative modelling of cognitive phenomena, by specifying required structures, classifications of sub-modules, relationship between among each modules, and so on. Its process is to deliver the required framework to

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formalize more informative modelling and exploration of different components and functions of the brain. Research aspect in computational cognitive modelling provides the concept of cognition and non-similar cognitive actions through developing information, action based understanding by representing computational models of mechanisms and processes. It combines descriptions of cognition in computer algorithms and programs. Finally, it produces executable computational models. Deep simulations are then performed at action based on the computational models. In this analysis, a cognitive architecture may be used for a wide, multilevel, interdisciplinary domain analysis of cognition [1].

III. Comparative Study of Cognitive Architecture

A. *ACT-R (Atomic Components of Thought-Rational)*

The Atomic Components of Thought (Anderson and Lebiere) provide their ACT-R cognitive architecture, which claim "contain the theory of the nature of human data, a theory of how this knowledge is deployed, and a theory of how that information is acquired. ACT-R is combined together of modules that make connection with a central production system via buffers. The amount of modules is not tokenized to the theory, and may be added as necessary. Theories and mechanisms have been derived from other cognitive architectures like Executive Process–Interactive Control (EPIC) cognitive architecture [2].

B. *SOAR (State, Operator And Result)*

The SOAR cognitive model uses problem links connected to a providing system that uses sub-goaling via impasse detection, learning, and chunking to draw a model of human mind. The cognitive model was creating iteratively with new modules and functionality being added to almost every new development.

C. *LIDA (Learning Intelligent Distribution Agent):*

Two assumptions through the LIDA architecture and its relating conceptual model are: a. Much of human cognition functions by means of frequently iterated (~10 Hz) interactions, called cognitive cycles, between conscious contents, the various memory systems and action selection.) These cognitive cycles, serve as the "atoms" of cognition of that higher-level cognitive processes are produced.

D. *CLARION (Connectionist Learning with Adaptive Rule Induction On-line):*

The CLARION cognitive architecture model is composed of four subsystems: the action centered subsystem (ACS), the non-action centered subsystem (NACS), the motivational subsystem (MS), and the meta-cognitive subsystem (MCS). Each one of these subsystems has both an implicit and explicit identity structure. The ACS uses neural networks to compute the quality of each action. It then selects the action with the highest quality.

E. *EPIC(Engineering, Procurement, Installation, and Commissioning):*

They presented (David Kieras and David Meyer) the EPIC cognitive architecture model and used it to explore human performance. The EPIC cognitive architecture builds upon the Model Human Processor and is composed of a collection of models of human performance, combined together by a refined theory, and modelled using performance information gathered from the review analysis. To validate the architecture, they used EPIC to examine common problems in HCI (e.g., processing multiple visual information sources). For each of these problems the predictions from EPIC were compared to actual human performance [3].

TABLE I
Comparison of Cognitive Architecture Underlying Several Criteria

Cognitive Architectures (CA) / **Criteria** (C)	**ACT-R** (CA)	**SOAR** (CA)	**LIDA** (CA)	**CLARION** (CA)	**EPIC** (CA)
Architecture Models (C)	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid
Goal Representation (C)	Stored in the central production system via the goal buffer	Supports automatic impas driven subgoals	Drives and goals are not built-in	Motivational subsystem creates and stores goals usi a goal structure.	Move complex instruction schedule,
Components (C)	Modules for perception (visual and aural).	Submitted to the clustering module and stored in short term memory.	Assigning meaning to incoming sensory data	Perceptual input represented as dimension/value pairs	Working Memory
Perception (C)	Modules for perception (visual and aural).	Submitted to the clustering module and stored in short term memory.	Assigning meaning to incoming sensory data	Perceptual input represented as dimension/value pairs	Very large architecture
Memory Types (C)	Contains goal,	Symbolic in short-	Working	Working memory in	Categorized

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	perception, relevant knowledge, and motor action in the various buffer in Short Term, Declarative and Procedural Memory.	term memory. Semantic, Episodic and a set of memories in long term memory.	Memory buffers in short term memory. Procedural and Episodic Memory in long term memory.	Short Term. Semantic, Episodic , Procedural memory in Long Term Memory	Various Memory
Learning Mechanism (C)	Declarative Memory, Learning Memory	Reinforcement, Semantic, Episodic and Chunking running Mechanism	Conceptual, Episodic, and Procedural Learning	The top-down and bottom-up learning	Cognitive processor, long term memory, production memory, detailed perceptual-motor interfaces
Problem-Solving Method (C)	Chunks Activate and Knowledge Extraction	Consist wide range of problem solving method and learn all aspects of action to process them	Non-cyclic problem solving methods	Choose required action by calculating Q-value at bottom level and rules in top level	Emergent working model.

IV. An Overview of Cognitive Architecture

A. *Role of Cognitive Architecture*

❖ From beginning constraining the design space, which is one does not build an infrastructure, for example, that requires more items to be kept in memory than in working memory (WM).

❖ Considering a particular design decisions, so that one can decide, for example, between dialogues which need of few keystrokes but difficult retrieval from memory or one that committing more keystrokes but is easier to remember.

❖ Calculating the total time for action performance with efficient accuracy to make decisions about how many people are needed to staff the performance of a repetitive operational task on a computer.

❖ Providing the fundamentals from which both to measuring training time and to inform training documentation to help the user determine in which situations which method is most efficient. Knowing which stages of activity take the longest time or produce the most errors, in directing research toward the aspects of human-computer interaction that will have strong future performance implications[4].

With the issue of using cognitive architecture to simulate humans, that list provides a useful summary of the early promises of cognitive architectures to the HCI community.

B. *Issues and Challenges of Cognitive Architectures:*

Despite the many conceptual advances that have occurred during three decades of research on cognitive architectures, and despite the practical use that some architecture have seen on real world problems, there remains considerable need for additional work on this important topic. In this section, we note some open issues that deserve attention from researchers in the area. The most obvious arena for improvement concerns the introduction of new capabilities. Existing architectures exhibit many of the capacities described in Section 3, but few support all of them, and even those achieve certain functionalities only with substantial programmer effort [5]. Some progress has been made on architectures that combine deliberative problem solving with reactive control, but we need higher efforts at unification along a number of other fronts are:

❖ Most architecture emphasize the generation of solutions to problems or the execution of actions, but categorization and understanding are also crucial aspects of cognition, and we need increased attention to these abilities.

❖ The focus on problem solving and procedural skills has drawn attention away from episodic knowledge. We need more research on architectures that directly support both episodic memory and reflective processes that operate on the structures it contains.

❖ Most architecture emphasize logic or closely related formalisms for representing knowledge, whereas humans also appear to utilize visual, auditory, diagrammatic, and other specialized representational schemes. We need extended frameworks that can encode knowledge in a variety of formalisms, relate them to each other, and use them to support intelligent behavior more flexibly and effectively.

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❖ Although natural language processing has been demonstrated within some architecture, few intelligent systems have combined this with the ability to communicate about their own decisions, plans, and other cognitive activities in a general manner.

❖ Physical agents have limited resources for perceiving the world and affecting it, yet little architecture addresses this issue. We need expanded frameworks that manage an agent's resources to selectively focus its perceptual attention, its effectors, and the tasks it pursues [6].

V. CONCLUSION

As we conclude process before, the cognitive architectures studied in this paper have number similarities and also many differences among them. First, ACT-R is a goal can be decomposed into subgoals and the new goals are added into the goal stack in ACT-R. A goal is subsequently removed from the goal stack once it is accomplishedpredominantly symbolic architecture, despite having some sub-symbolic modules. Second, SOAR is only the architecture which delivers with minimum flexibility than the CLARION and LIDA cognitive model of architecture and built-in functionalities are not available in this architecture. The CLARION architecture is having bottom-up and top-down learning methodologies. The effective features of CLARION architecture model which includes top-down and bottom-up functionalities.

In dual cases, the defined constrains and outcomes of a previous action are used in the generating of a new rule, which is also subject to next refinements. The five architectures compared with this paper have their own advantages and disadvantages, depending on its intended situational factors. They were compared in this paper regarding their theoretical mechanisms and how they can be used to provide different cognitive capabilities. We expect in this paper how new users to get benefit from this analysis while looking for a cognitive architecture to use in their projects. In a future work, we intend to focus on more pragmatically issues related to the software implementation of the architectures. In this paper, we presented a research in the area of cognitive architectures by providing a comparative survey between several of cognitive architecture. These cognitive architectures may allow the user to identify the most appropriate architecture for our system.

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