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Symbolic Architectures for Cognition

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ABSTRACT: A Cognitive architecture refers to a theory about the structure of the human mind. The architecture is the fixed structure that provides the frame within which cognitive processing in the mind takes place. This paper describes what an architecture is and how it enters into cognitive theories of the mind. In this we aim at symbolic architectures, the family that includes the architectures central to computer science. The requirements and the functions of cognitive architectures has been identified. Two cognitive architectures Act* and Soar which are relevant to the study of Human Cognition are used to illustrate matters in detail.

KEYWORDS: Cognitive Architecture, Symbolic Architecture

I. THE ROLE OF ARCHITECTURE IN COGNITIVE SCIENCE

In cognitive science the notion of architecture has come to take on a quite specific and technical meaning, deriving from computer science. There the term stands for the hardware structure that produces a system that can be programmed. It is design of a machine that admits the distinction between hardware and software [Agrawal]. The concept of architecture for cognitive science then is the appropriate generalization and abstraction of the concept of computer architecture applied to human cognition: the fixed system of mechanisms that underlies and produces cognitive behavior. As such, an appropriate starting place is a description of an ordinary computer architecture.

The human can be described at different system levels. At the top level is the knowledge level, which describes the person as having goals and knowing things about the world, in which knowledge is used in the service of its goals by the principle of rationality. The person can operate at the knowledge level only because it is also a symbol level system, which is a system that operates in terms of representations and information processing operations on these representations. The symbol level must also be realized in terms of some sub state and the architecture is that sub state defined in an appropriate descriptive language. For computers it turns out to be the register transfer level, in which bit-vectors are transported from one functional unit to another, subject to gating by control bits. For humans it is the neural-circuit level, which currently seems well described as highly parallel interconnections that process a medium of continuous signals.

This arrangement of system levels seems very special- it is after all the eye of the needle through which systems have to pass to be able to be intelligent. Nevertheless there is an immense variety of architectures and an immense variety of physical substrates in which they can be implemented. No real appreciation exists yet for this full double variety or its consequences, except that they are exceedingly large and diverse. It is relatively easy to understand a given architecture when presented, though there may be a fair amount of detail to wade through. However it is difficult to see the behavioral consequence of architecture, because it is so overlaid by the programs it executes. And it is extremely difficult to compare different architectures, for each presents its own total framework that can carve up the world in radically different ways. Despite these difficulties cognitive science needs to determine the architecture that underlies and supports human cognition.

The architecture does not by itself determine the behavior. The other main contributors are the goal the person is attempting to attain, the task environment within which the person is performing, and the knowledge the person has. The first is not only the knowledge of conditions or situations desired, but also the commitment to govern behavior to obtain such conditions, The second is the objective situation, along with the objective constraints about how the person

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can interact with the situation. The third is the subjective situation of the person in relation to the task. The knowledge involved in accomplishing any task is diverse and extensive and derives from multiple sources.

The goal, task and knowledge of course constitute the knowledge level characterization of a person. The architecture's primary role is to make that possible by supporting the processing of the symbolic representations that hold the knowledge. If it did so perfectly then the architecture would not appear as an independent factor in the determination of behavior any more. But the knowledge-level characterization is far from perfect.

What the notion of the architecture supplies is the concept of the total system of mechanisms that are required to attain flexible intelligent behavior. Normally psychological investigations operate in isolation, though with a justified sense that the mechanisms investigated (memory, learning, memory retrieval, etc) are necessary and important. The architecture adds the total system context within which such separate mechanisms operate, providing additional constraints that determine behavior. The architecture also brings to the fore additional mechanisms that must be involved and that have received less attention in experimental psychology.

A theory of the architecture is a proposal for the total cognitive mechanism, rather than for a single aspect or mechanism. A proposed embodiment of an architecture, such as a simulation system, purports to be a complete mechanism for human cognition. The form of its memory embodies a hypothesis of the way human action specifications are created or modified, and so on[Newell1987]

II. REQUIREMENTS ON THE COGNITIVE ARCHITECTURE

We need to understand the requirements that shape human cognition, especially beyond the need for universal computation. The cognitive architecture must provide the support necessary for all these requirements. The following is a list of requirements that could shape the architecture[Newell]

1. Behave flexibly as a function of the environment
2. Exhibit adaptive(rational, goal oriented) behavior.
3. Operate in real time.
4. Operate in a rich, complex, detailed environment
   a. Perceive an immense amount of changing detail
   b. Use vast amounts of knowledge
   c. Control a motor system of many degrees of freedom
5. Use Symbols and abstractions
6. Use Language, both natural and artificial
7. Learn from the environment and from experience
8. Acquire capabilities through development
9. Live autonomously within a social community
10. Exhibit self awareness and a sense of self

Human cognition can be taken to be an information processing system that is a solution to all of the listed requirements plus perhaps others that have not learned about. Flexibility, the grounds for claiming that human cognition is built on an architecture, is certainly a prominent item, but it is far from the only one. Each of others plays some role in making human cognition what it is.

Our problem is what is implied by the list for the shape of the architecture. For each requirement there exists a body of general and scientific knowledge, more or less well developed. But cognition is always the resultant of the architecture plus the content of the memories, combined under the impress of being adaptive. This tends to conceal the inner structure and reveal only knowledge level behavior. Thus extracting the implications for the architecture requires analysis.

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Functional requirements are not the only sources of knowledge about the cognitive architecture. We know that cognitive architecture is a realized in neural technology and that it was created by evolution. Both of these have major effects on the architecture.

III. THE NATURE OF THE ARCHITECTURE

We now describe the nature of the cognitive architecture. This is to be given in terms of functions rather than structures and mechanisms. In part this is because the architecture is defined in terms of what it does for cognition. In general the architecture provides support for a given function rather than the entire function. Because architecture provides a way in which software can guide behavior in flexible ways, essentially all intellectual or control functions can be provided by software. Only in various limiting conditions of speed, reliability, access to the architectural mechanisms themselves, and like-is it necessary to perform all of the certain functions directly in the architecture. It may, of course, be efficient to perform functions in the architecture that could also be provided by software.

The following list gives known functions of the architecture.

1. Memory
   a. Contains structures that contain symbol tokens
   b. Independently modifiable at some grain size
   c. Sufficient memory
2. Symbols
   a. Patterns that provide access to distal symbol structures
   b. A symbol token in the occurrence of a pattern in a structure
   c. Sufficient symbols
3. Operations
   a. Processes that take symbol structures as input and produce symbol structures as output.
   b. Complete compossibilities
4. Interpretation
   a. Processes that take symbol structures as input and produce behavior by executiong operations
   b. Complete interpretability
5. Interaction with the external world
   a. Perceptual and motor interface
   b. Buffering and interrupts
   c. Real-time demands for action
   d. Continuous acquisition of knowledge

We stress that these functions are only what are known currently. Especially with natural systems such as human cognition, but even with artificial systems, we do not know all the functions that are performed.

The first four items of the list of functions provide the capability for being a symbol system: memory, symbols, operations and interpretation. However none of these functions is the function representation of the external world. Symbols do provide an internal representation of function, but the representation of the external world is a function of the computational system as a whole, so that the architecture supports such representation but does not itself provide it.

The first requirement is for memory, which is to say, structures that persist over time. Memory is composed of structures called symbol structures because they contain symbol tokens. At some sufficiently large grain size the memory structures must be independently modifiable. There are two reasons for this. First, the variety of the external world is combinatorial-it comprises many independent multi valued dimensions located throughout space and time. Only a combinational memory structure can hold information about such a world. Second, built-in dependencies in the memory structure, while facilitating certain computations, must ultimately interfere with the ability of the system to compute according to the dictates of the environment.

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Symbol tokens are patterns in symbol structures that provide access to distal memory structures, that is, to structure elsewhere in memory. The need for symbols arises because it is not possible for all of the structure involved in a computation to be assembled ahead of time at the physical site of the computation. Thus it is necessary to travel out to other parts of the memory to obtain the additional structure. In terms of knowledge level this is what is required to bring all of the system's knowledge to bear on achieving a goal. It is not possible to know in advance all the knowledge that will be used in a computation. Thus the ingredients for a symbol mechanism are some pattern within the structures being processed, which can be used to open an access path to a distal structure and a retrieval path by means of which the distal structures can be communicated to inform the local state of the computation.

The system is capable of performing operations on symbol structures to compose new symbol structures. There are many variations on such operations in terms of what they do in building new structures and in terms of how they depend on other symbol structures. Some structures have the property of determining that a sequence of symbol operations occurs on specific symbol structures. These structures are called variously codes, programs, procedures, routines, or plans. We now have all the ingredients of a symbol system. These are sufficient to produce indefinitely flexible behavior.

In addition to providing flexibility, symbol systems provide important support for several other requirements in the first list. For adaptability they provide the ability to represent goals and to conditionalize action off of them. For vast amounts of knowledge they provide symbol structures in which the knowledge can be encoded and arbitrarily large memories with the accompanying ability to access distal knowledge as necessary. For symbols, abstractions, and language they provide the ability to manipulate representations. For learning they provide the ability to create long-term symbol structures.

Symbol systems are components of a larger embedding system that lives in a real dynamic world, and their overall function is to create appropriate interactions of this larger system with the world. The interfaces of the large system to the world are sensory and motor devices. Exactly where it makes sense to say the architecture ends and distinct input output subsystems begin depends on the particular system.

The fourth function arises from an implication of a changing environment- the system can not know in advance everything it needs to know about such an environment. Therefore the system must continually acquire knowledge from the environment and do so at time constants dictated by the environment. Symbol systems have the capability of acquiring knowledge, so in this respect at least no new architectural function is involved.

IV. EXAMPLE ARCHITECTURES: ACT* AND SOAR

We now have an analysis of the functions of a cognitive architecture and the general way it responds to the requirements of our first list with two example architectures, Act*[Anderson] and Soar[Laird, Newell and Rosenbloom]. Act* is the first theory og cognitive architecture with sufficient detail and completeness to worthy of the name. It represents a long term development. Soar is another entry as a cognitive theory. Its immediate pre history is as an AI architecture. The overview of ACT* and SOAR architectures are given in the following figures.

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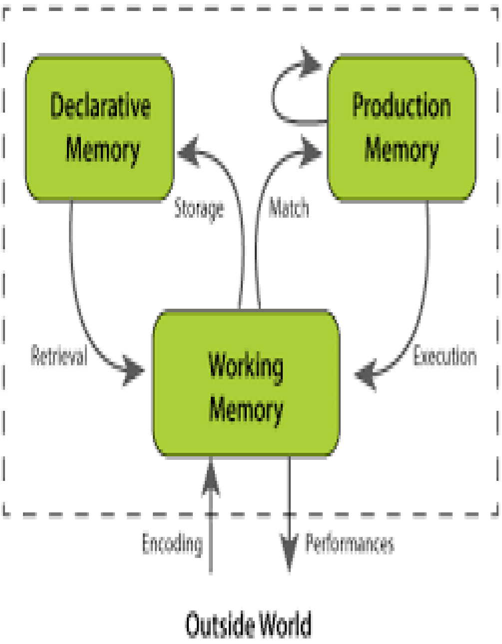
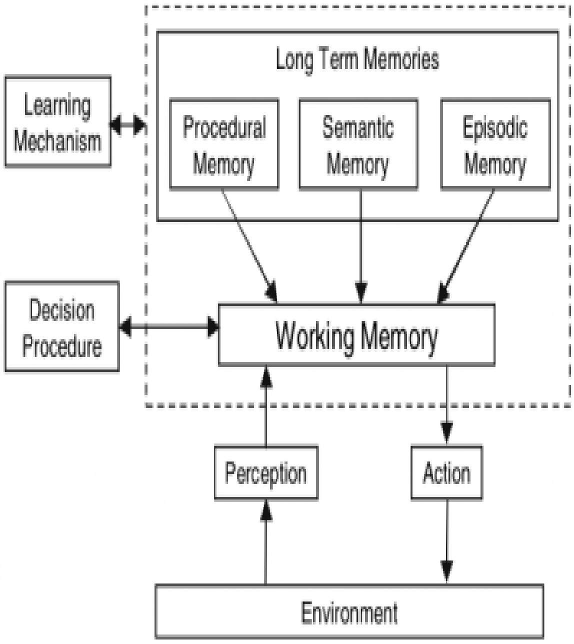


Fig1: ACT*



Fif2: SOAR

Both the Act* and Soar have memory hierarchies that range in both time constants and volume. Act8 has two totally distinct memories, and Soar ha one that is similar to one of Act*'s memory. Both symbolic cognitive architectures are built around production systems.

V. THE USES OF THE ARCHITECTURE

Given that the architecture is a component of the human cognitive system, it requires no justification to spend scientific effort on it. Understanding the architecture is a scientific project in its own right. The architecture, however, as the frame in terms of which all processing is done and the locus of the structural constraints on human cognition, would appear to be the central element in a general theory of cognition. The following are the uses of cognitive architectures:

1. The architecture has large effects on cognition, but that these effects can be summarized in a small set of gross parameters. The list of parameters are-the size of short term memory, the time for an elementary operation, the time to make a move in a problem space, and the rate of acquisition into long-term memory.
2. To perform complex task involving a sequence of basic operations in an arrangement conditional on the input data. The architecture dictates both the basic operations and the form in which arrangements of operations are specified.
3. An architecture provides a form of unification for cognitive science.

VI. CONCLUSION

The requirements and functionalities of cognitive architectures and the analysis of these with two example architectures Act* and Soar has been given in detail. The paper concluded by raising some of the issues that reveal additional major steps required to pursue adequate theory of Cognitive architecture. One of the issue is acquiring capabilities through development. Another issue is the relationship of emotion, feeling, and affect to cognition.

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REFERENCES

1. Agrawal, D.P. Advanced Computer Architecture, Washington, DC: Computer Society Press
2. Anderson, J.R. The Architecture of Cognition, Cambridge, MA:Harvard University Press
3. Hayes-Roth, B. A blackboard architecture for control, Artificial Intelligence 26:251-321.
4. Klahr, D.. Information processing approaches to cognitive development, CT:JAI Press, pp.131-183
5. Laird, J.E, Newell, A.,&Rosenbloom, P. S., Soar: An architecture for general Intellignce. Artificial Intelligence 33(I):1-64
6. Newell A., Production Systems: Models of Control Structures, In W. C. Chase ed. The Psychology of Computer Vision, Newyork; McGraw Hill
7. Newell. A., Physical Symbol Systems, Cognitive Science 4:135-183
8. Newell. A.,(Spring) Unified Theories of Cognition, The William James Lectures, Psychology Department, Harvard University, Cambridge, MA