# CSC: Classic Paper Review/Analysis

## Title and Author

Title **Computer Science as Empirical Inquiry: Symbols and Search**

Author **Allen Newell and Herbert A. Simon**

## Summary/Hook

Influential paper/lecture guiding the course of computer science and related fields through the idea of the Physical Symbol System Hypothesis. This is defined as "A physical symbol system has the necessary and sufficient means for general intelligent action." The theory put forth is that intelligent systems have internal workings which interpret, interact and manipulate symbols. The intent of this hypothesis is to (at the time) transform computer science from an experimental field to an empirical one on the basis that computer science has built a solid foundation upon the basis of symbols and all their relevant processes. Newell and Simon also get into the theoretics of AI, especially the heuristic functions that are entailed, and differentiate weak and strong AI.

## Knowledge Relating to the Cognitive Science Program Learning Outcomes

1. 8. Embodiment, Emergence, and Distributed Cognition

   Our understanding of the systems requirements for intelligent action emerges slowly. It is composite, for no single elementary thing accounts for intelligence in all its manifestations. There is no "intelligence principle," just as there is no "vital principle" that conveys by its very nature the essence of life. But the lack of a simple deus ex machina does not imply that there are no structural requirements for intelligence. One such requirement is the ability to store and manipulate symbols.

2. 2. Symbol Systems

   At any instant of time the system will contain a collection of these symbol structures. Besides these structures, the system also contains a collection of processes that operate on expressions to produce other expressions: processes of creation, modification, reproduction and destruction. A physical symbol system is a machine that produces through time an evolving collection of symbol structures. Such a system exists in a world of objects wider than just these symbolic expressions themselves.

3. 9. Formal Systems and Theories of Computation

The finite state control system was always viewed as a small controller, and logical games were played to see how small a state system could be used without destroying the universality of the machine. No games, as far as we can tell, were ever played to add new states dynamically to the finite control--to think of the control memory as holding the bulk of the system's knowledge. What was accomplished at this stage was half the principle of interpretation--showing that a machine could be run from a description. Thus, this is the stage of automatic formal symbol manipulation.

4. 1. Foundational Assumptions

The twenty years of work since then has seen a continuous accumulation of empirical evidence of two main varieties. The first addresses itself to the sufficiency of physical symbol systems for producing intelligence, attempting to construct and test specific systems that have such a capability. The second kind of evidence addresses itself to the necessity of having a physical symbol system wherever intelligence is exhibited. It starts with Man, the intelligent system best known to us, and attempts to discover whether his cognitive activity can be explained as the working of a physical symbol system.

5. 10. Algorithms and Automota

Physical symbol systems must use heuristic search to solve problems because such systems have limited processing resources; in a finite number of steps, and over a finite interval of time, they can execute only a finite number of processes. Of course that is not a very strong limitation, for all universal Turing machines suffer from it. We intend the limitation, however, in a stronger sense: we mean practically limited. We can conceive of systems that are not limited in a practical way, but are capable, for example, of searching in parallel the nodes of an exponentially expanding tree at a constant rate for each unit advance in depth