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Classic Paper 2: Review/Analysis

Title and Author

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

Author: *Allen Newell and Herbert A. Simon*

Summary/Hook

This paper famously discusses symbols, and why Newell and Simon believe them to be the root of intelligent action. The main drive of this paper is the discussion of the *Physical Symbol System Hypothesis*, the Laws of Qualitative Structure throughout the sciences, and the discussion of the *Heuristic Search Hypothesis*. These concepts are thoroughly described, and examples of their use in research and modeling intelligence are shown.

Knowledge Related to the Cognitive Science Program Learning Outcomes

1. **Symbol Systems**

   Let us return to the topic of symbols, and define a *physical symbol system*. The adjective "physical" denotes two important features: (1) Such systems clearly obey the laws of physics--they are realizable by engineered systems made of engineered components; (2) although our use of the term "symbol" prefigures our intended interpretation, it is not restricted to human symbol systems.

2. **Foundational Assumptions**

   We can now state a general scientific hypothesis--a law of qualitative structure for symbol systems: The *Physical Symbol System Hypothesis*. A physical symbol system has the necessary and sufficient means for general intelligent action. By "necessary" we mean that any system that exhibits general intelligence will prove upon analysis to be a physical symbol system. By "sufficient" we mean that any physical symbol system of sufficient size can be organized further to exhibit general intelligence.

3. **Formal Systems and Theories of Computation**

The roots of the hypothesis go back to the program of Frege and of Whitehead and Russell for formalizing logic: capturing the basic conceptual notions of mathematics in logic and putting the notions of proof and deduction on a secure footing. This effort culminated in mathematical logic--our familiar propositional, first-order, and higher-order logics. It developed a characteristic view, often referred to as the "symbol game."

4. **Psychological Investigations**

Here we have had a continuum of theories from the points of view usually labeled "behaviorism" to those usually labeled "Gestalt theory." Neither of these points of view stands as a real competitor to the symbol system hypothesis, and this for two reasons. First, neither behaviorism nor Gestalt theory has demonstrated, or even shown how to demonstrate, that the explanatory mechanisms it postulates are sufficient to account for intelligent behavior in complex tasks. Second, neither theory has been formulated with anything like the specificity of artificial programs.

5. **Neural Networks**

Heuristic Search Hypothesis. The solutions to problems are represented as symbol structures. A physical symbol system exercises its intelligence in problem solving by search--that is, by generating and progressively modifying symbol structures until it produces a solution structure. 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.