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New Psychology Theory Enables Computers to Mimic Human Creativity

A dealer in antique coins gets an offer to buy a beautiful bronze coin. The coin has an emperor's head on one side and the date "544 B.C." stamped on the other. The dealer examines the coin, but instead of buying it, he calls the police. Why?

Solving this "insight problem" requires creativity, a skill at which humans excel (the coin is a fake -- "B.C." and Arabic numerals did not exist at the time) and computers do not. Now, a new explanation of how humans solve problems creatively -- including the mathematical formulations for facilitating the incorporation of the theory in artificial intelligence programs -- provides a roadmap to building systems that perform like humans at the task.

Ron Sun, Rensselaer Polytechnic Institute Professor of Cognitive Science, said the new "Explicit-Implicit Interaction Theory," recently introduced in an article in Psychological Review, could be used for future artificial intelligence.

"As a psychological theory, this theory pushes forward the field of research on creative problem solving and offers an explanation of the human mind and how we solve problems creatively," Sun said. "But this model can also be used as the basis for creating future artificial intelligence programs that are good at solving problems creatively."

The paper, titled "Incubation, Insight, and Creative Problem Solving: A Unified Theory and a Connectionist Model," by Sun and Sèbastien Hèlie of University of California, Santa Barbara, appeared in the July edition of Psychological Review. Discussion of the theory is accompanied by mathematical specifications for the "CLARION" cognitive architecture -- a computer program developed by Sun's research group to act like a cognitive system -- as well as successful computer simulations of the theory.

In the paper, Sun and Hèlie compare the performance of the CLARION model using "Explicit-Implicit Interaction" theory with results from previous human trials -- including tests involving the coin question -- and found results to be nearly identical in several aspects of problem solving.

In the tests involving the coin question, human subjects were given a chance to respond after being interrupted either to discuss their thought process or to work on an unrelated task. In that experiment, 35.6 percent of participants answered correctly after discussing their thinking, while 45.8 percent of participants answered correctly after working on another task.

In 5,000 runs of the CLARION program set for similar interruptions, CLARION answered correctly 35.3 percent of the time in the first instance, and 45.3 percent of the time in the second instance.

"The simulation data matches the human data very well," said Sun.

Explicit-Implicit Interaction theory is the most recent advance on a well-regarded outline of creative problem solving known as "Stage Decomposition," developed by Graham Wallas in his seminal 1926 book "The Art of Thought." According to stage decomposition, humans go through four stages -- preparation, incubation, insight (illumination), and verification -- in solving problems creatively.

Building on Wallas' work, several disparate theories have since been advanced to explain the specific processes used by the human mind during the stages of incubation and insight. Competing theories propose that incubation -- a period away from deliberative work -- is a time of recovery from fatigue of deliberative work, an opportunity for the mind to work unconsciously on the problem, a time during which the mind discards false assumptions, or a time in which solutions to similar problems are retrieved from memory, among other ideas.

Each theory can be represented mathematically in artificial intelligence models. However, most models choose between theories rather than seeking to incorporate multiple theories and therefore they are fragmentary at best.

Sun and Hèlie's Explicit-Implicit Interaction (EII) theory integrates several of the competing theories into a larger equation.

"EII unifies a lot of fragmentary pre-existing theories," Sun said. "These pre-existing theories only account for some aspects of creative problem solving, but not in a unified way. EII unifies those fragments and provides a more coherent, more complete theory."

The basic principles of EII propose the coexistence of two different types of knowledge and processing: explicit and implicit. Explicit knowledge is easier to access and verbalize, can be rendered symbolically, and requires more attention to process. Implicit knowledge is relatively inaccessible, harder to verbalize, and is more vague and requires less attention to process.

In solving a problem, explicit knowledge could be the knowledge used in reasoning, deliberately thinking through different options, while implicit knowledge is the intuition that gives rise to a solution suddenly. Both types of knowledge are involved simultaneously to solve a problem and reinforce each other in the process. By including this principle in each step, Sun was able to achieve a successful system.

"This tells us how creative problem solving may emerge from the interaction of explicit and implicit cognitive processes; why both types of processes are necessary for creative problem solving, as well as in many other psychological domains and functionalities," said Sun.