2021 Knuth Prize is Awarded to Moshe Vardi

The 2021 Donald E. Knuth Prize is awarded to Moshe Y. Vardi of Rice University for outstanding contributions that apply mathematical logic to multiple fundamental areas of computer science. Vardi's work has greatly increased our understanding of myriad computational systems. It has also led to significant practical applications such as industrial hardware and software verification. The major themes of Vardi's contributions are the use of automata theory and logics of programs to algorithmically prove correctness of system designs; the analysis of database issues – including query-evaluation complexity, data updates, and others – using finite-model theory; characterizations of complexity classes such as P in terms of logical expressions; and the analysis of multi-agent systems such as distributed computation systems, via epistemic logic. Testimony to the central significance of this body of work is Vardi's citation count, well over 53,000 (all citation counts are from Google Scholar, May 2021).

Automata-theoretic verification of system design.
A key result, among others, is presented in "Reasoning about infinite computations" (with P. Wolper, FOCS 1983, Information and Computation, 1994, Goedel Prize 2000). The paper transforms statements about the correctness of a system into equivalent statements about the behavior of a finite automaton that has infinite length input words or infinite input trees. This sparked interest in such automata, e.g., Buechi automata. This automata-based approach laid the basis of automated design checkers such as Bell Lab's SPIN, winner of the 2001 ACM Software System Award for systems with lasting influence. The elegant technical details of the paper required new results concerning both automata and logics of programs. Exponential time bounds achieved by this approach improve much higher bounds (including non-elementary time bounds) of other approaches. A follow-up paper, "An automata-theoretic approach to automatic program verification" (with P. Wolper, LICS 1986, 2006 LICS Test-of-Time Award, over 2100 citations) showed how the approach yields optimal model-checking algorithms. All this work led to the 2006 ACM Kanellakis Award for Theory and Practice. Other industrial tools rely on Vardi's work on the development of languages for verification, the Property Specification Language (PSL) and SystemVerilog Assertions (SVA).

Database theory.
"The complexity of relational query languages" (STOC 1982) analyzed the computational complexity of the two query languages of relational databases, relational calculus and relational algebra, as well as extensions of both languages. The paper currently has over 1800 citations. "Conjunctive-query containment and constraint satisfaction" (with P. Kolaitis, J. CSS 2000) shows the equivalence of the two problems in the title, the first a central issue in databases and the second a basic tool in artificial intelligence. The paper also obtains new complexity results for both problems. The paper won the 2008 ACM PODS Test-of-Time Award. Theoretical results on data integration and data exchange (e.g., "On the foundations of the universal relation model", TODS 1984, with D. Maier and J.D. Ullman) have been implemented in commercial systems such as IBM's Data Websphere Interchange.

Descriptive computational complexity.
The above-cited STOC 1982 paper also presents a characterization of the complexity class P, specifically P is the class of languages expressible in first-order logic with a least fixed point operator (known as "the Immerman-Vardi Theorem", derived independently also by N. Immerman). Such characterizations of complexity classes in terms of logical expressibility, the goal of descriptive computational complexity, give us basic insights into computation and computability. The paper won a 1982 IBM Outstanding Innovation Award. Vardi and T. Feder studied the computational complexity of constraint satisfaction problems (STOC 1993, SIAM J. Comput. 1998 with over 1100 citations). The

paper won SIGLOG's 2018 Alonzo Church Award for Outstanding Contributions to Logic and Computation. In particular it posed the Dichotomy Conjecture that every CSP problem is either in P or is NP-complete. Their evidence for the conjecture stimulated much further research and it was finally proved by others (proof completed independently by A. Bulatov and D. Zhuk, 2017).

Knowledge in distributed systems.
Vardi and coauthors developed a widely applicable theory about facts known or unknown to various agents in a shared environment. This issue is of fundamental importance for distributed computation, as well as diverse areas including economics and artificial intelligence. The theory is based on various logical systems that model knowledge, and gives tools to design, analyze, and verify correctness of multi-agent systems. Research papers (such as Halpern, Vardi, J.CSS 1989) culminated in the book "Reasoning about knowledge" (Fagin, Moses, Halpern, Vardi, 1995 and 2003) with over 5400 citations.

Vardi's contributions through technical service include establishing and chairing the Federated Logic Conference, chairing numerous program committees, and Editor-in-Chief of the reinvigorated Communications of the ACM. He has supervised 31 doctoral and post-doctoral students.

Moshe Vardi is well-deserving of the Donald E. Knuth Prize awarded for "high-impact, seminal contributions to the foundations of computer science".

Prize Committee: Harold Gabow (Chair, U. Colorado), Noam Nisan (Hebrew U.), Dana Randall (Georgia Tech), Ronitt Rubinfeld (MIT), Madhu Sudan (Harvard U.), and Andy Yao (Tsinghua U.).