

# Yuri Gurevich: The Evolution of a Research Life from Algebra through Logic to Computer Science.

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Yuri Gurevich is a man whose life embraces three worlds—Russia, Israel and United States—and whose research spans three disciplines—algebra, logic and computer science—all of which shaped the 20th century. In each of these research areas Gurevich set milestones and became a leading figure. Indeed the outstanding constant in his life is his courage and strength to think about the *fundamentals* which underly problems of *impact* in the field.

He was born on May 7, 1940, in Nikolayev (Ukraine) and was moved by destiny through Stalingrad (41-42), Chimkent (Uzbekistan, 42-44), Cheliabinsk (44-59, school and Polytechnic) to Sverdlovsk where he studied, graduated and taught at the Ural University (59-64, 65-71) and where he married Zoe, a student of mathematics and later system programmer who gave him two daughters, Hava and Naomi, and accompanies his life.

Gurevich started his research in algebra where he became famous through his work on ordered abelian groups. For his diploma in 1962 he solved [1]<sup>1</sup> one of the problems which was listed as open in Petr Kontorovich’s algebra seminar. Gurevich learned logic from Kleene’s *Introduction to Metamathematics* and in 1962 heard about Tarski’s program of classifying elementary theories into decidable and undecidable. A year after Tarski and Smielew announced the decidability of the elementary theory of ordered abelian groups but then found an error in their proof, Gurevich proved the decidability of the first-order theory of ordered abelian groups [3], which became his PhD thesis (1964) and made him an assistant professor at the University of Krasnoyarsk (64-65).

Since the theorems in the then known algebra of ordered abelian groups were not first-order, and the standard extensions of classical first-order logic (like monadic second-order logic) give rise to undecidable theories, Gurevich wondered whether there is a logic that fits ordered abelian groups, so that the corresponding theory expresses most of the relevant algebra but yet is manageable and hopefully decidable. He proved that the extension of the elementary theory of ordered abelian groups with quantification over so-called convex subgroups, even though it is much richer than the elementary theory and expresses virtually all known algebra of ordered abelian groups, is not only decidable [25], but allows the elimination of elementary quantifiers. When in 1973, via Krasnodar (71-72) and Tbilisi (Georgia, 72-73), Gurevich emigrated to Israel (Beer Sheva,

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<sup>1</sup> The numbers in brackets refer to the Annotated Publication List at <http://research.microsoft.com/gurevich/>, except where marked by *reference below*.

74-82), he met Saharon Shelah, studied Shelah's seminal paper on the theory of order (Annals of Mathematics, 1975) and solved in [26, 27] most of its numerous conjectures, which led to a still ongoing fruitful collaboration between the two logicians (see the survey [64]).

For Hilbert's *Entscheidungsproblem*, one of the major themes of mathematical logic in the twentieth century, Gurevich [6] resolved the most difficult of the prefix-predicate classes and thereby completed the prefix-predicate classification of the fragments of the restricted predicate calculus as decidable or undecidable. He found a general explanation of the classifiability phenomenon [13], confirmed it for the classification of fragments with function symbols [18] and conjectured the classification of fragments with equality and at least one function symbol, one of the most difficult problems in the area. The conjecture was later proved by Saharon Shelah. Details can be found in [2] (reference below).

The year 1982, when the University of Michigan appointed Gurevich, marks the beginning of his commitment to computer science and of his close collaboration with Andreas Blass from the mathematics department there. Gurevich shaped the two emerging fields of finite model theory and of average case complexity. It started with his first talk to a computer science conference [41], where Gurevich saw Moshe Vardi applying the definability theorem of first-order logic to databases, which were assumed to be possibly infinite - and immediately worried whether such classical theorems would remain valid if only finite databases were allowed. The answer turned out to be negative [60], the counter-example to Lyndon's interpolation theorem [72] gave a uniform sequence of constant-depth polynomial-size (functionally) monotone boolean circuits not equivalent to any (however nonuniform) sequence of constant-depth polynomial-size positive boolean circuits. Other landmark contributions to finite model theory are the characterization of primitive recursive (resp. recursive) functions over finite structures as log-space (resp. polynomial time) computable [51], the characterization of the inflationary fixed-point extension of first-order logic as equi-expressive with its least fixed-point extension on finite structures [70], the boundedness of every first-order expressible datalog query [83], etc.

Gurevich's contributions to complexity theory are no less important. He solved special but important cases of NP-hard problems [54], on time-space trade-offs [87], on linear time [82], and critically analysed some non-traditional approaches [81,80], but above all we see Gurevich work here on average case complexity, side by side with Leonid Levin. An NP-hard problem, when equipped with a probability distribution, may become easy. For example, for random graphs with  $n$  vertices and a fixed edge probability, the algorithm of [71] solves the Hamiltonian Circuit Problem in average time  $O(n)$ . In 1984, Leonid Levin generalized the NP-completeness theory to such distributional (DNP) problems and constructed one DNP problem that was hard in the average case. [76] provides new hard cases and shows that Levin's original deterministic reductions are inadequate, which led Levin and Venkatesan to define more powerful randomizing reductions. [88,93,94,96,97] contains pioneering work towards establishing the average-case intractability of important problems.

Reconsidering Turing's thesis and the fundamental problem of semantics of programming languages led Gurevich to his epochal concept of Abstract State Machines [74,92,103,141]. It has already triggered hundreds of publications, in finite model theory [109,120,135], in complexity theory [118,121] and in numerous areas of applied computer science, e.g. programming languages, protocols, architectures and embedded control software (see the survey in [1] (reference below) and [77,89,98,106,107,111,116,117,119,121,122,137-140]); even more importantly it is changing the way we think about high-level software design and analysis. In this extraordinarily rich, deep and wide ranging life in research, all the strands are woven together. By investing that wealth into building and leading the Foundations of Software Engineering group at Microsoft Research (since August 1998), Gurevich professes his conviction that there is nothing more practical than a good theory.

## References

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2. E. Börger and E. Grädel and Y. Gurevich, *The Classical Decision Problem*. Perspectives in Mathematical Logic, Springer-Verlag Berlin etc. (1997), pp. XII+482.

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