Boris (Boaz) Trakhtenbrot
1921–2016

Boris (Boaz) Abramovich Trakhtenbrot (Борис Абрамович Трахтенброт; בועז טרכטנברוט), a founding father of computer science, passed away September 19, 2016 at age 95, in Rehovot, Israel. His beloved wife, Berta (née Rabinovich), died three years prior. He is survived by two sons, Mark Trakhtenbrot and Yosef Halakhmi, five grandchildren, and two great-grandchildren.

Trakhtenbrot was born in Brichevo, a shtetl in Northern Bessarabia (now Moldova), about which he always spoke fondly. He studied at the Moldavian Pedagogical Institute in Kishinev, Chernivtsi National University (Ukraine), Kiev Mathematical Institute (Ukraine), and (unoÿcially) at Moscow Univer-sity. After completing his doctorate in 1950, under Petr S. Novikov, he took a position at the Belinsky Pedagogical Institute in Penza (Western Russia), and later—in 1960—joined the just-established Mathematical Institute at Novosi-birsk Akademgorodok, where he established and headed the Theory of Automata and Mathematical Linguistics Department. He received a Doctor of Sciences degree in 1962.

During the Stalin era, Boaz had troubles as many other scientists in the USSR. He was barred from attending international congresses in the west, to which he had been invited.

In 1980, Boaz immigrated to Israel and joined Tel Aviv University's School of Mathematical Sciences. There he was instrumental in the major growth phase of its computer science department. He remained vitally active for many years after his oÿcial retirement in 1991.

Today, Boaz is universally admired as a founding father and long-standing pillar of the discipline of computer science. He was the field's pre-eminent distinguished researcher, and a most illustrious trailblazer and disseminator. He made very many deeply significant contributions to theoretical computer science, on decidability problems in logic, finite automata theory, the connection between automata and monadic second-order logic, complexity of algorithms, abstract complexity, algorithmic logic, probabilistic computation, program verification, the lambda calculus and foundations of programming languages, programming semantics, semantics and methodology for concurrency, networks, hybrid systems, and more. He was unmatched in combining farsighted vision, unfaltering commitment, masterful command of the field, technical virtuoso, æsthetic ex-

pression, eloquent clarity, and creative vigor with humility and devotion to students and colleagues.

No fewer than three famous theorems in theoretical computer science bear Trakhtenbrot's name:

- **Trakhtenbrot's Theorem** (1950): *The validity of (first-order) statements that hold true for all finite universes is undecidable.*
- **The Büchi-Elgot-Trakhtenbrot Theorem** (1962): *Finite automata and weak monadic (second-order) logic have the same expressive power.*
- **The Borodin-Trakhtenbrot Gap Theorem** (1964): *There are arbitrarily large (computable) gaps in the hierarchy of complexity classes.*

Trakhtenbrot's doctoral dissertation inaugurated finite model theory. His subsequent Novosibirsk period was very productive; his regular seminar there was legendary. He introduced the use of monadic second-order logic as a spec-ification formalism for the infinite behavior of finite automata. This logic has turned out to be very fundamental; various temporal logics are just "sugared" fragments of monadic logic. And he was among the very first to consider time and space eÿciency of algorithms (using what he called "signalizing functions") and to speak about abstract complexity measures (independently and in parallel with similar developments by Western theoreticians).

Trakhtenbrot initiated the study of topological aspects of ω-languages and operators and provided a characterization of operators computable by finite automata. Furthermore, he supplied solutions to special cases of the Church synthesis problem, later solved by Büchi and Landweber. The equivalence with automata and the solvability of Church's problem laid the necessary under-pinnings for the development of formalisms for describing interactive systems and their properties. These have led to tools for algorithmic verification and automatic synthesis of correct implementations and for the advanced algorith-mic techniques that are now embodied in industrial tools for verification and validation.

His justly famous and truly elegant Gap Theorem (proved independently by Allan Borodin in the West) and his development of the "crossing sequence" method were groundbreaking. His paper on "auto-reducibility" provided a turn-ing point in abstract complexity. In the USSR, these works quickly became very influential, and, in the US, complexity took over as the central preoccupation of theoretical computer science.

Trakhtenbrot was at the same time a master pedagogue and expositor. His book, *Algorithms and Automatic Computing Machines*, first written in Russian in 1957, was translated into English and a dozen other languages, and is recog-nized worldwide as the first important text in the field. He played the key rôle in the dissemination of Soviet computer science research in the West, writing surveys on such topics as Soviet approaches to brute force search (*perebor*).

His later works dealt with various aspects of concurrency, including data flow networks, Petri nets, partial-order versus branching-time equivalence, bi-

simulation, real-time automata, and hybrid systems. All told, he published some one hundred articles, books, and monographs.

A roll call of Trakhtenbrot's students reads like the "Who's Who" of theoret-ical computer science in the USSR. His sixteen doctoral students are: Miroslav Kratko (1964), Nikolai Beljakin (1964), Janis Barzdins (1965), Valery Nepom-nyaschy (1967), Alexei Korshunov (1967), Mars K. Valiev (1969), Valery Aga-fonov (1969), Djavkathodja Hodjaev (1970), Zoya Litvintseva (1970), Rūsiņš Freivalds (1972), Anatoli Vaisser (1976), Vladimir Sazonov (1976), Michael Dekhtyar (1977), Irina Lomazova (1981), Alex Barel (1984), and Alexander Rabinovich (1989). Moreover, a whole generation of computer scientists was shaped by his textbooks on automata theory. Besides building the computer science department in Novosibirsk, he collaborated with computer designers in the Soviet Union and helped in the establishment of a department of theoretical informatics in Jena (East Germany). The Latvian school of computer science flourished under the tutelage of his students, Barzdins and Freivalds.

Trakhtenbrot received numerous prizes and recognitions for his contributions, including the following:

- In June 1991, Tel Aviv University's Department of Computer Science organized "An International Symposium on Theoretical Computer Science in honor of Boris A. Trakhtenbrot on the occasion of his Retirement and Seventieth Birthday". The event took place in Tel Aviv, and many of the world's foremost scientists gathered. (See the report by Val Breazu-Tannen in *SIGACT News*, vol. 22, no. 4, Fall 1991, pp. 27–32, http://portalparts.acm.org/130000/126546/fm/frontmatter.pdf.)

- In the same year, Trakhtenbrot's colleagues and former students from Latvia published a volume, "Dedicated to Professor B. A. Trakhtenbrot, father of Baltic Computer Science, on the occasion of his 70th birthday" (*Baltic Computer Science*, *Lecture Notes in Computer Science*, vol. 502, Springer-Verlag, May 1991).

- The Friedrich Schiller University in Jena bestowed on him the degree of doctor *honoris causa* in October 1997.

- At the *Computer Science Logic (CSL)* conference in Brno in 1998, a special session was organized to celebrate "50 years of Trakhtenbrot's Theorem", in which Boaz took part.

- In July 2001, in honor of his eightieth birthday and his "very important contribution to Formal Languages and Automata", Trakhtenbrot gave the keynote address at the joint session of the *International EATCS Colloquium on Automata, Languages and Programming (ICALP)* and of the *ACM Symposium on Theory of Computing (SIGACT)*, held in Crete (http://acm-stoc.org/stoc2001).

- In 2006, the School of Computer Science at Tel Aviv University held a "Computation Day Celebrating Boaz (Boris) Trakhtenbrot's Eighty-Fifth Birthday" (http://www.cs.tau.ac.il/~nachumd/Boaz.html).

- In 2008, the volume, *Pillars of Computer Science: Essays Dedicated to Boris (Boaz) Trakhtenbrot on the Occasion of His 85th Birthday* appeared in Springer's Festschrift series (*Lecture Notes in Computer Science*, vol. 4800, Springer-Verlag, 2008), with 34 scientific contributions by his friends and colleagues, themselves leading mathematicians, logicians, and com-puter scientists.

- In 2011, the *European Association for Theoretical Computer Science (EATCS)* honored him with their highest award, the Distinguished Achievements Award. The laudation (https://www.eatcs.org/images/awards/LAUDATIO2011.pdf) reads:

> For over half a century, Trakhtenbrot has been making seminal contributions to virtually all of the central aspects of theoreti-cal computer science, inaugurating numerous brand-new areas of investigation. . . . The entire body of his work demonstrates the same unique melding of supreme mathematical prowess, combined with profound depth and thoroughness. His operative style has always been patient in-depth survey of existing literature, uncompromising evaluation and critical comparison of existing approaches, followed by extraordinary and prescient contributions.

Trakhtenbrot's contributions are astounding under any measure; how much more so when consideration is given to the fact that he worked under very adverse conditions: persecution, lack of support, almost no access to foreign meetings, and so on. His undaunted spirit should serve as an inspiration to all.

His wisdom, courage, and generosity will be sorely missed.