Oscar H. Ibarra: Computer Scientist Par Excellence

by Michael A. Palis*

Over the past thirty years, arguably no other field of scientific endeavor has had a broader and more profound impact on human society than computer science. It has spawned many innovations, such as the personal computer, digital media, and the World Wide Web, that have become so much a part of our lives that we have come to take them for granted.

Dr. Oscar H. Ibarra is a world-renowned computer scientist who has made deep and lasting research contributions to computer science, particularly in the areas of algorithms, theory of computation, computational complexity, and parallel computing. The Institute for Scientific Information (ISI) lists him as one the most highly cited researchers of our time – one of the "top influential researchers from 21 broad subject categories in life sciences, medicine, physical sciences, engineering, and social sciences who have contributed to the progress of science through their insight and accomplishments".

Dr. Ibarra is a pioneer in the area of design and analysis of algorithms. He introduced a powerful technique called *fully polynomial time approximation schemes* for solving NP-hard problems, which are computational problems that have no known efficient algorithms (i.e., algorithms that run in polynomial time). It is generally accepted that NP-hard problems cannot be solved in polynomial time, i.e., they are most likely intractable. Whether or not this is indeed true is one of the most famous long-standing open problems in computer science (the P vs. NP question). NP-hard problems arise in a wide variety of areas, such as computational biology, network engineering, robotics, computer-aided design, resource management and scheduling, program optimization and verification, and mathematical programming. Fully polynomial time approximation schemes allow the design of polynomial time algorithms for NP-hard problems that produce approximate solutions with certain performance guarantees. More specifically, the technique allows one to trade off the "closeness" of the approximation (to the optimal solution) with the efficiency of the algorithm: you can get the algorithm to be as close to optimal as possible but with an attendant increase in its time complexity. While researchers were aware that certain NP-hard problems could be "approximately solved" by polynomial time algorithms, Dr. Ibarra's discovery that some could be solved in polynomial time with as small a fractional error as desired was a breakthrough. This pioneering work has motivated researchers to investigate the existence of polynomial time approximation algorithms for various NP-hard problems – an area of investigation that remains active up to the present day. Fully polynomial time approximation schemes are now standard material in textbooks for algorithm design.

Dr. Ibarra is also regarded as one of the world's top researchers in the theory of computation and computational complexity and his contributions to these areas are deep and influential. A fundamental line of inquiry in the theory of computation is determining whether a problem can be solved by *any* algorithm at all. Often, such a problem can be cast as a "decision problem" whose solution is a simple yes-or-no answer. An example of a decision problem is the Halting Problem, which

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can be stated as follows: "Given a computer program P and an input x, does P, when executed on input x, eventually halt?" A decision problem is said to be decidable if there is an algorithm that solves it; otherwise it is undecidable. The Halting Problem is undecidable, a result first proved by Alan Turing in 1936. Dr. Ibarra is widely recognized for having developed novel techniques to determine the decidability and undecidability of many important decision problems in automata theory, formal languages, and programming languages. In particular, he has established some of the strongest results known on the undecidable properties of programs and abstract machines.

Dr. Ibarra has done pioneering work in computational complexity theory, which is concerned with classifying problems according to their difficulty or "complexity" – that is, the amount of resources (e.g., time or space) needed to solve the problem on a specific computational model (e.g., a sequential or parallel machine). A related concern is characterizing the class of problems that can be solved within a given resource bound (e.g., the class of problems that can be solved in polynomial time on a sequential machine). Although intuitively one would expect that "if you have more resources, you can solve more problems", it turns out that this statement can either be true or false depending on the resource and computational model under consideration, and in many cases, the answer is not yet known. Dr. Ibarra introduced and popularized *translational* or *padding* techniques that led to breakthroughs in the establishment of tight complexity class hierarchies for various models of computation. These techniques are widely used in complexity theory.

A prolific scholar with over 300 publications, Dr. Ibarra also has made important contributions to various other areas, including parallel computing, program verification, and membrane computing. The last is a promising new area of investigation on parallel and distributed computational models inspired by the architecture and the functioning of living cells, as well as the organization of cells in tissues, organs, and other higher order structures such as colonies of cells (e.g., of bacteria). Dr. Ibarra has made fundamental contributions, many of which are milestone results. In particular, he solved an important problem that has been open since the beginnings of membrane computing. For this and other contributions, he was awarded the First P Prize in Membrane Computing in 2003.

Dr. Ibarra's scientific career began at the University of the Philippines where he graduated with the B.S. degree in Electrical Engineering in 1962. He then pursued graduate studies at the University of California at Berkeley, where he received the M.S. and Ph.D. degrees in Electrical Engineering in 1965 and 1967, respectively. He taught at Berkeley for two years before moving to the University of Minnesota in 1969, where he remained for twenty years. It was at Minnesota that Dr. Ibarra gained worldwide recognition as a leading theoretical computer scientist. In 1984, he was awarded the John Simon Guggenheim Memorial Foundation Fellowship, the only recipient in the field of computer science that year. In 1989, he left the cold winters of Minnesota for the year-round tropical climate of the Santa Barbara campus of the University of California, where he has remained up to the present time. At UCSB, he served in leadership positions, including Chair of the Computer Science Department, and continued to gain recognition for his exemplary research. He achieved the much coveted "trifecta" of awards that

Helene de Rode, president of the European Academy of Sciences, presenting Dr. Ibarra with the Blaise Pascal Medal in Computer Science during the EAS awards ceremony held at Egmont Palace in Brussels in September 2007.

few computer science researchers have achieved: Fellow of the Institute of Electrical and Electronics Engineers (1992), Fellow of the Association for the Advancement of Science (1993) and Fellow of the Association for Computing Machinery (1995).

In 2001 Dr. Ibarra received the IEEE Computer Society's Harry H. Goode Memorial Award, which is awarded to a single individual for outstanding achievement in the information processing field. His citation reads: "for outstanding contributions to the information processing field, particularly in the design and analysis of algorithms, theory of computation, computational complexity, and parallel computing". In 2003 he was elected member of the European Academy of Sciences, an international organization of distinguished scientists and engineers from over 60 countries that elects its members based solely on their research accomplishments. It counts as members 65 Nobel Prize and Fields Medal winners. In 2007 the EAS awarded Dr. Ibarra the Blaise Pascal Medal for Computer Science, citing his "outstanding and demonstrated personal contribution to science and technology, and the promotion of excellence in research and education" and recognizing his research contributions to the theory of computing, design and analysis of algorithms, computational complexity, parallel computing, formal verification, and membrane computing. In 2008 he was elected Foreign Member of Academia Europaea in the Informatics Section. The Academia has over 2000 members, including 40 Nobel Laureates, from 35 European countries and 8 non-European countries who are leading experts in the physical sciences and technology, biological sciences and medicine, mathematics, the letters and humanities, social and cognitive sciences, economics, and law. In 2007 (the year of his nomination), the Informatics Section had only 7 Foreign Members. Dr. Ibarra is now a member of this elite group.

Dr. Ibarra has garnered numerous other awards and distinctions for his contributions to research and education: the Japan Society for the Promotion of Science Invitation Fellowship for Research (2002); the Philippine-American Academy of Science and Engineering Founder's Lectureship Award in Engineering (2002); the University of the Philippines Alumni Association Distinguished Alumnus Award as the Outstanding Professional in the field of Mathematics, Statistics, and Computer Science (2003); the First P Prize in Membrane Computing (2003); the Nokia Visiting Research Fellowship to the University of Turku, Finland (2007); and the UK Royal Academy of Engineering Distinguished Visiting Fellowship (2008).

Dr. Ibarra holds editorships in numerous computer science journals. Currently, he is Editor-in-Chief of the *International Journal of Foundations of Computer Science*, and Editor of *Theoretical Computer Science*, the *Journal of Parallel and Distributed Computing*, *Grammars: A Journal of Mathematical Research on Formal and Natural Languages*, and *Mathematics Applied in Science and Technology*. He has also served on the editorial boards of the *IEEE Transactions on Computers*, the *IEEE Transactions on Parallel and Distributed Systems*, and the *Journal of VLSI Signal Processing*. He is on the advisory committee of the *IEEE Technical Committee on Parallel Processing* and is a member of the *IFIP Working Group on Cellular Automata*. He has served on the technical program committee of numerous international conferences and workshops and has delivered invited/keynote speeches and lectures at conferences and universities worldwide.

Throughout his academic career, Dr. Ibarra excelled not only as a scholar but also as an educator. He has supervised 22 Ph.D. students (including yours truly), who have themselves gone on to establish successful careers in academia and industry. They owe much of their success to him. He is a great mentor and inspiring influence to his students. In 2002 his former students and professional colleagues hosted a workshop, *Computer Science: From Theory to Practice*, in Singapore in his honor on the occasion of his 60th birthday. The workshop is a fitting tribute to an individual who not only has achieved great academic and scholarly success but also is a valued teacher, mentor, colleague and friend. **PSL**