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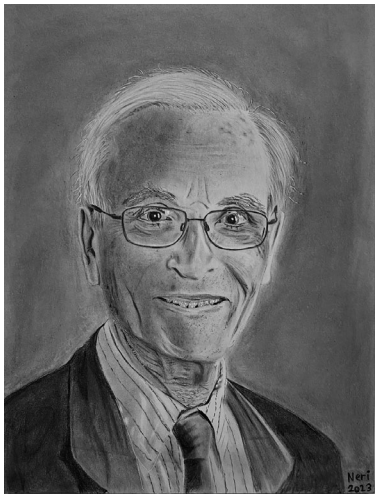
In Memory of Jacob Ziv

On Saturday, 25 March 2023, Distinguished Professor Jacob Ziv passed away.

Our Information Theory community, the IEEE, and the academic world has lost a towering figure in Information Theory in any scale—a researcher who belongs to the selected group of a handful of pioneering scientists, which impacted the field in a profound manner.

We shall not provide here a detailed list on all his fundamental scientific work in general, but only mention some of his most prominent contributions to information theory during more than six decades of his research career.

His most notable contribution, in association with Abraham Lempel, who also passed away just a month and half before, is indisputably the Lempel–Ziv (LZ) algorithm, which is a milestone contribution, reported in three seminal articles [3], [4], and [5]. The LZ algorithm is an innovative and practical methodology that enables data compression, along with perfect reconstruction, in an efficient way, without assuming any probabilistic mechanism to govern the data. The uniqueness of this invention is that it is an excellent example of the rare combination between theory and practice: the beautiful theory of the interplay between individual sequences and finite-state machines, on the one hand, and the excellent performance along with an extremely simple and efficient implementation, on the other hand. Thanks to this performance and simplicity, it has become part of almost every standard data compression package in every computer, every cellular phone, and in many communication protocols. It is no wonder that this contribution has been recognized by the most prestigious 1977 IT Society Paper Award, as well as many other awards later. It also has an extremely strong interdisciplinary aspect, since the main building block of the LZ algorithm is useful in a variety of information processing tasks beyond data compression, such as universal decoding [6], universal hypothesis testing and classification [8], and universal prediction [9].



A portrait of Distinguished Professor Jacob Ziv, drawn by Neri Merhav.

The LZ articles are considered to be a landmark in source coding theory and they have triggered a vast amount of research activity since their publication. The literature contains hundreds of articles on LZ that range the whole spectrum from the most theoretical to the most practice-oriented works. Ziv has, in fact, established the individual-sequence approach to information theory, which is a most important branch today in information theory research. This has also major practical implications, as no statistical description of the data is required. Throughout the whole history of information theory, there is a handful of exceptional scholars who demonstrate comparable accomplishments.

But the scientific contribution of Ziv spans far beyond the LZ monumental achievement. Starting from his early notable contributions on multiterminal source coding,

2692-4080 © 2024 IEEE
Digital Object Identifier 10.1109/MBITS.2024.3370115
Date of current version 9 July 2024.

which sparked new thrust to information theory away from the classical single user paradigm. His coauthored work on general functionals satisfying the date-processing theorem [1] is cited through the five decades since it has been published, and it inspires to this very day different research venues in information theory. His fundamental work, in association with Aaron Wyner, [2] on compression with side information has been widely recognized, and won the 1976 Information Theory Society Paper Award. Nowadays, it is considered to be a standard tool in multiterminal information theoretic models spanning way beyond source coding (for example, communications aided by relays (cloud radio access networks), which is a basic feature of future generation (6G) wireless technologies. Other classical contributions, together with Moshe Zakai, relate to estimation performance bounds. For example, the Ziv–Zakai bound on the minimum mean square error is one of the tightest up to date, decades after its original derivation. He has made notable contributions, addressing basic theoretical problems, of central practical importance, such as classification problems [8] and universal procedures in source and channel coding/decoding, which were mentioned earlier. Ziv has been active for decades, and his more recent contributions focus on different aspects and fundamental ingredients of classification and universal data compression. His studies through the many years of his activity demonstrate deep insights and exceptional originality, and they immediately turn to be classical references, just after their publications.

The impact of Ziv's technical contributions is profound, in the every meaning of this word. He is one of the very few whose fundamental contribution is world acclaimed, way beyond the professional circles of the information theory society of even the whole IEEE. It is enough just to mention the LZ compression algorithm, which literally has changed the very way communications and data storage and processing are conceived. The LZ compression algorithm has an unparalleled impact on the daily lives of computer users, as well as in innumerable operations of commercial electronic products worldwide. The evolution of computing and communications technology continuously pose extremely severe demands on storage, bandwidth, and speed. LZ compression plays the pivotal role in meeting these demands, making the use of lossless data compression pervasive in day-to-day computing.

Ziv was one of the very few world's major leaders in the area, and this is put in evidence by the exceptional professional recognitions he has gained. We will mention here just a few: The 1994 Israel Award for Exact Sciences, the 1995 Hamming Medal, the 1995 Marconi Prize, the 1997 Shannon Award, the 2008 BBVA Foundation Frontiers in Knowledge Award in the category of Information and Communication Technologies for his seminal, groundbreaking data compression algorithm, the 2017, EMET Prize, and finally, the 2021 IEEE Medal of Honor, the highest IEEE recognition for fundamental contributions to information theory and data compression technology, and for distinguished research leadership.

Apart of being the most senior information theorist in Israel through the last six decades, Ziv contributed vitally to the Israeli academic life in any possible aspect. He served as a the Dean of the Electrical Engineering and Computer Science Faculty at Technion (1974–1976), the Vice Technion President for Academic Affairs (1978–1982), and the Chairperson of the Israeli Universities Planning and Grants Committee (1985–1991). He was member of the Israel Academy of Sciences, (serving as its President: 1995–2004) he was also: Foreign Member of the US National Academy of Engineering, Foreign Member of the American Academy of Arts and Science, Foreign Member of the American Philosophical Society and a Member of the European Academy of Sciences and Arts, and a Foreign Member of the US National Academy of Science.

He was a modest and kind person. He continued his scientific work until the very last days of his life, focusing on his resent work with Cassuto on distributed information compression, as used in DNA sequence compression, where reference sequences are shared among senders and receivers.

Both of us were lucky to take information theory courses taught at the time by Jacob, and even more so, being supervised by him on our doctoral studies. We kept learning from him as students and colleagues, through all the passing decades. His legacy as a researcher and as a person will continue to inspire us, as well as many others, for years to come. We, personally miss Jacob very much, and it is hard for us to accept the sad fact that we cannot talk to him anymore, and obtain his clever comments and advice.

May he rest in peace.

Neri and Shlomo

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