Against all Odds: The Amazing but Most True Story of Aviezri Fraenkel and his Special Favorite: The Responsa Project or The Multi-Faceted Contributions of Aviezri Fraenkel to Information Retrieval and the Related Areas

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It is for me a great privilege — and a great joy — to write this short note (which should really be a book) about the achievements of Aviezri Fraenkel in conceiving, building and directing the Responsa Project, his "special favorite" by his own confession (see the first paragraph on his home page http://www.wisdom.weizmann.ac.il/~fraenkel) and his many contributions to Information Retrieval (and some of its related areas), mostly motivated by his ardent desire to assure the success, robustness and longevity of the Responsa Project (Respor). By asking me in the mid sixties to join the Respor team, then in its early stages of formation, in order to design and develop the computational-linguistic component of Respor, he inadvertently shaped a large part of my academic career in research, teaching and consulting, and in fact of my entire life, for almost 35 years. I was struggling then with my Ph.D. thesis on the theory of finite automata with infinite tapes and trees, a then obtuse domain on the borderline of mathematical logic and computer science (now a thriving subject of research with applications to automatic verification of large software systems). Still, he was successful in making me — as was the case indeed with him, and with all the other major players of Respor (researchers, programmers, rabbis) — breathe, eat and drink Responsa and Full-Text systems for more than twenty years. I shall always be more than grateful to him for giving me the chance and the opportunity to be part of — and a few years later, lead, with his most generous and unselfish support and advice — this most fascinating endeavor, which opened new perspectives in (among others) Judaica and Rabbinic studies.

Unlike the case of combinatorial games and number theory (items I2 and I3 in this issue), one cannot do justice to Aviezri's contributions to the field by simply enumerating his many papers with a short comment on each (which we shall do anyway towards the end of this note). The importance and influence of his work goes well beyond its formal written aspects. It lies in his mapping of new ideas and concepts, in his obstinate stand against prevailing academic trends, in his untiring efforts to prove the importance, feasibility and

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efficiency of the proposed scheme, in supervising and educating large groups of M.Sc. and Ph.D. students, and in taking part, over a great span of time (almost forty years), in all aspects of the Respor activities: theory and practice, research and applications, grants and funding, users' education and the dissemination and popularization of Respor aims and achievements. Not only was he dealing with an obscure and strange corpus (the Responsa literature — "what is this?") written in an "exotic" language (rabbinical Hebrew with some Talmudic Aramaic), planning to process it for computerized storage and retrieval using a novel, improbable and unproved technology (the full-text method), but even the targeted potential users (jurists and experts in Jewish law, rabbis and rabbinical courts, historians, linguists, humanities' scholars, and more) were hostile to the project and reluctant to even give it a try.

For the readers of this Journal, a few words of clarification about Information Retrieval (IR), the Responsa literature, and the full-text method are probably needed. Information (Storage and) Retrieval is that branch of computer science (and, in some of its facets, also a branch of library sciences, of information science, of documentation, and the like) that deals with the problems, solutions, methodologies and technologies for storing and processing large (in fact, huge) amounts of textual documents (papers, abstracts, reports, letters, memos, etc) in such a way so as to be able to retrieve later from this database just those few documents that are pertinent to a user's need as formulated in the form of a "query" from time to time. The time-honored method of assigning (manually, or, in some approaches, automatically) to each document, a few keywords and descriptors that somehow capture the "essence" of the document and its main subjects, and then processing them (as computer files) to point to the documents that satisfy some Boolean combination of such terms, was at that time (and still is, in some circles) at the core of the IR methodology.

In about 1963 Aviezri was pondering the question of how computers can be used to open the gates of the Responsa's very rich and complex literature to browsing and retrieval. This literature consists of an impressive collection of "queries and responses", written essentially in Hebrew, that spans more than a thousand years and has its origin in almost all regions of the world, but especially in East (and some parts of West) Europe, North Africa, the Middle East and parts of Asia. It is estimated that about 1800 authors have contributed to it, producing some 3500 printed volumes (collections of responsa) totaling more than half-a-million documents, not counting lost or unpublished material. These queries were posed by Jewish individuals and communities from all over the world to the outstanding rabbis and authorities in each generation. The queries were on matters of Jewish code of life and behavior, and the decisions rendered became valuable precedents of Jewish law. Since the bulk of the problems dealt with in this literature reflect real-life situations, the historical-sociological milieu is depicted in these documents in a true-to-life fashion that is quite uncommon in similar corpora of other cultures. The Responsa literature is now recognized as an invaluable storehouse of information of interest to scholars in law, history, economics, philosophy, religion, sociology, linguistics, folklore, etc, not to mention Jewish and rabbinical studies. Personages, realia, scholars, wars and kings, dramatic events as well as such minutiæ as birth, marriage and death, recipes,

taxes, medical practices, all these and more provide the scholar with a unique opportunity to recapture life in those times and places with a remarkable accuracy.

Trying to solve the problem of efficient retrieval from this vast ocean, so as to help the user locating the few documents that are relevant to him in a specific situation, is what attracted Aviezri to the IR field. Very rapidly he came to the conclusion, however, that no indexing by keywords scheme, clever and complex as it may be, can solve the problem, even remotely. He had then the bright idea (independently raised and tried on a small scale somewhat earlier by J. Horty from Pittsburgh) of storing the documents themselves (as much of them as possible, of course) in the computer, without any prior keywording or processing, just "as is". A computerized system is then built to accept from the user a query consisting of any combination of words and phrases with various positional and Boolean restrictions that the user judges will be satisfied in the relevant documents, and to scan the entire corpus to find those documents that indeed satisfy the given conditions. This is the core of the full-text method; its efficiency is achieved by automatically indexing every word in the document (except maybe for some common words such as *the*, *an*, etc.), making it searchable by the system.

The full-text system associated with the Responsa corpus (as well as the corpus itself), the core of which was gradually developed by Aviezri and his team from the mid-sixties to the mid-seventies, was one of the very first to be developed anywhere, certainly the first (and till the late eighties the only) such system in Hebrew, and most probably the largest one (in any language) developed at that time in Humanities' studies context. [2]

By now it should be quite obvious to the readers of this journal that the full-text approach is the one they actually use daily — along with tens (hundreds?) of millions of other users — when searching for information in the Internet, using popular search engines such as Google, AltaVista, or Lycos. The entire contents of billions of pages on the Internet are made searchable by this approach, and even a word that occurs only once in this mind-boggling ocean of information can be located and retrieved in a split second. The indexing and filing schemes used to achieve such a feat are basically identical to the ones developed and used by Respor 30 years ago. Any thought of manually (or even automatically) assigning keywords or descriptors to this storehouse of documents, that grows by the millions each day, would probably deserve to be qualified as lunatic.

It would therefore be quite hard to believe today the cold shoulder ("hostility" would be a better word), with which the approach was met in most (though not all) research and academic circles in IR.

Note for example that Yehoshua Bar-Hillel, one of the most respected and influential philosophers of language in the late fifties and early sixties (whose group also proved some of the most important properties of formal languages), wrote in 1962 a devastatingly critical review [3] on the then proposed schemes for "the mechanization of literature search-

[2]For more on the Responsa Literature and on Respor as it was in the early eighties, see [Cho1990] listed in the references part of [30]; in order to read [30], an as yet unpublished paper in English to which we shall refer later, click on its title in the "Recent Reprints" paragraph on Aviezri's homepage.

[3]Yehoshua Bar-Hillel, Theoretical Aspects of the Mechanization of Literature Searching, Digitale Informationswandler, Vieweg & Sohn, Braunschweig, 1962, pp. 406–443.

ing", whose section 5 was entitled "The Unavoidability of Indexing", which says it all, and whose last sentence was: "...unless the assumption of the universal use of a strictly regimented language of science is made, any scheme of directly comparing a request formulation with a straight-forward one-to-one encoding of the original documents [the full-text of the document, YC] must be regarded as wholly utopian and unsubstantiated".

More to the point, however, I vividly remember a visit I paid in the summer of 1975 to one of the best-known figures of IR at that time, in his office at the Department of Computer Science of one of the leading universities on the US East coast. This respected and prolific researcher was an ardent supporter of the "vector space" IR model and of the experimental projects developed to research it. When I tried to explain to him our radically different approach and the achievements we reached after almost ten years of development, he got so furious and angry, claiming that the idea is dumb and absurd, that it can never and will never be successful, that we are "mixing apples and oranges", and the like, that it became clear that no reasonable exchange of differing academic viewpoints on this issue was possible. At the end of the meeting, however, there was an atmosphere of reconciliation and he even invited me to spend the evening with him at his lovely home near the lake (which I did).

One must remember, in this context, that the technology itself was not friendly to the full-text approach. Disk memory — essential for storing the full text of the documents rather than a few assigned keywords — was very expensive then and with a very small range; 20 Megabytes was the most a typical university project could get then, compared to 20 Gigabytes available today on every home PC and for about a hundredth of the price. Data input to the computer could be done only through 80-column punch cards or through perforated tape. No terminals (not to mention PCs) or communications were available, and everything was to be done offline, with the output printed on high-speed printers with basically upper case characters only. Two anecdotes can illustrate that milieu, and the peculiar Aviezri way in handling it. When the time came to input some of the responsa documents to the computer, Aviezri asked IBM engineers in Israel to supply us with a card-punching machine with Hebrew characters that can be printed on the top of the card, for proofreading purpose; which they graciously did. When he asked however for the mechanism to go right-to-left, as it should in Hebrew, rather than in the standard left-to-right direction, they refused, claiming that the market was not big enough for the engineering modifications required. Proofreading in the "wrong" direction being, however, an almost impossible task (try it), Aviezri baffled the engineers by asking them to have the Hebrew fonts imprinted upside down. This way, by turning the punched and printed-on-the-top card upside down, you could easily and naturally read the text in the "right" direction. Whoever knows this ingenious researcher will immediately recognize here the special Aviezri Fraenkel touch.

On another occasion, in the mid-sixties, while worried by the slow and expensive pace of inputting responsa documents to the computer, he met over lunch, with the famous, brilliant and prolific inventor Jacob Rabinow [4] whose "Reading Machine" (in fact an OCR

[4]Jacob Rabinow (1904 - 1999), earned 229 patents for his inventions, and beside the "Reading machine", he was also the inventor of the "Letter Sorting Machine" of the US Postal Service, the first

machine for English) was already in use, and asked him about OCR for Hebrew. "No problems", he said, and took with him a copy of the Rivash [5] Responsa, to consult with his engineers. After a few months and some promptings, he finally wrote that he could handle the problem. The first machine would cost a million dollars, but the second one only half-a-million. To which Aviezri cabled back: "Will be glad to order the second one". Vintage Fraenkel (dry) humor ...

The history of Respor, from its modest beginnings in the mid-sixties to its great success in the new millennium, when the expensive Respor CD-ROM — still recognized as the best of its kind — is sold by the tens of thousands, in Israel and abroad, bringing knowledge and wisdom to its purchasers and a nice income to the university, is indeed, with its strange ups and downs, a very exciting and curious one. If you were to look only at the picturesque gallery of its admirers, attackers and visitors, including Prime Ministers and ministers, ambassadors, diplomats and other high officials, scholars, rabbis, scientists and academicians, both from Israel and abroad, on one hand, and the large collection of various original documents associated with its activities for almost forty years, on the other, it would make for a dramatic — and in some aspects, hilarious — story. A very short overview of that history, written by Fraenkel a few years ago from his personal viewpoint appears in [30]. The full Respor book is still, however, to be written.

Before closing this section to go on and review Aviezri's publications in IR and in some related areas, we should mention again the overwhelming impact he had, through the development, popularization and dissemination of Respor, on the study of the Responsa literature in Rabbinical and other Jewish and general humanities' scholarly circles. From an obscure and not much studied area, open only to the most erudite of scholars, and available only partly in a few specialized libraries, it is rapidly becoming a popular source of research, citations and quotations, thanks to the fact that a whole library of almost 300 books, encompassing some 100 million words, with a clever and highly efficient computerized search and retrieval system associated with it, is now available in every small college and many homes. More can be said about that, but since I doubt if our gentle and patient editor would approve of yet another introductory item on "Aviezri Fraenkel and Rabbinical Studies", we'll have to make do with this short remark.

Methodical and infinitely curious as he is, once Aviezri decided that he must find an efficient IR system for the Responsa, he took upon himself to study in depth the whole IR field, with its then available tools and techniques. This effort culminated in the publication a few years later of [1], a masterly overview of the state of the art in this field, highly praised by adherents and opponents of IR alike. Because of the novelty of the approach, the unfamiliar contents and language of Responsa, and the fact that Respor R & D touched upon problems in Computer Science, Information Retrieval, Legal Information Computer applications, and Jewish Studies, Aviezri took upon himself to appear before

disc memory computer storage, the first self-regulating clock and much more. For a short biographical sketch see http://web.mit.edu/invent/www/inventorsR-Z/rabinow.html, and for a nice portrait of him see http://www.cag.lcs.mit.edu/ anne/inventors/JR/JR2-big.jpg

[5]Rivash - Rabbi Yehuda beribbi Sheshet Perfet, one of the leading rabbinical authorities of Spain and North Africa in the 14th century

as many audiences as possible to preach for the viability of the full-text approach and the importance of Respor. Besides addressing professional circles in computer science [5] (a successful talk that was later published in an expanded solicited form [6] as a separate pamphlet in J. Schweitzer Verlag), he also addressed the International Symposium of the Society of Technical Writers and Publishers [2], the Association of Orthodox Jewish Scientists [3], the Symposium on Information Systems in Chemistry [4], the Fifth World Congress of Jewish Studies [8], and the Third Symposium on Legal Data Processing in Europe [9]. Implicit in these efforts was the conviction that keyword-indexing schemes were hopelessly deficient, at least in the context of large corpora of general interest. Using a certain model of keyword indexing and abstracting, he was even able to rigorously prove, in [14], that these tasks were, in a well-defined mathematical sense, "inherently difficult problems" — an endeavor which would surprise no one familiar with Aviezri's fascination with complexity issues.

The usefulness of applying natural language processing techniques (or computational linguistics, as they were more commonly known then) to the textual content of documents in order to enhance the precision and recall of IR systems was for a long time a heated topic of discussion. The generally accepted paradigm, though (at least till the mid-eighties), was that such techniques are foreign to IR, superfluous, and cannot enhance the results in any significant way. This attitude was supported of course by some "solid experimental results", and was endorsed by the most famous names in the field. This only strengthens our admiration for Aviezri's temerity and unfailing insight when he asked me in the mid-sixties to develop a practical automatic module for morphological analysis of Hebrew to be embedded in the Respor full-text system, and a few years later, to develop a full-fledged computerized component for Hebrew morphology suitable to the on-line version of Respor, an effort that took us three years to complete. The results were published in [7] and [11], but are implicitly embedded in almost all other publications of Respor. Just as an example, dealing with large dictionaries and lists of words and their possible compression led to the research reported in [17] and [18], and even [16], that deals with detecting and correcting OCR errors, has some implicit linguistic ingredients in it. Incidentally, moving the system from an offline context to an online one required the development of new and much more efficient algorithms for queries' processing, and these are reported in [23].

Again, the implications of these linguistic ideas and efforts of the seventies and early eighties had a great impact later, in the late eighties and the nineties, on the building — in a much more general framework — of solid and advanced intelligent processing modules for Hebrew in Israel, but we will refrain from dealing any more with that topic here. Note also that from the mid-nineties most advanced full-text IR commercial packages (though not yet most search engines on the Internet) already contain some (rudimentary or advanced) linguistic (at least morphological) processing embedded in the system.

Another two directions in which Aviezri and his Respor team had to go against the trends of the times were feedback systems and compression techniques. Can an IR system's efficacy be enhanced by letting the user present a query to the system, analyze the results and give feedback to the system by telling it which documents retrieved were actually relevant and which were not, thus allowing the system to use this information

to get better results from a second round of the queries? Most experiments done in the framework of the SMART system gave negative results. Aviezri and his Ph.D. student Rony Attar had the idea of restricting the feedback to a "local" context. Conducting very arduous experiments (because of the technology limitations at that time), they received excellent — even surprising — results, which were published in [10] and [13], but were largely (again) ignored by the active IR community. (These results were later strongly confirmed and expanded by the work of my graduate student Shay Hanani in his M.Sc. thesis, unpublished).

On a second front, with the advance of very large inexpensive memory storage, interest in compression techniques began to fade, due to the impression that there is now no need to compress, since any memory needed is in practice available. Aviezri thought otherwise. The more memory that is available, he argued, the more you need, since new applications will immediately emerge that were impractical before, and they will again push further the borderline of the possible, the feasible and the desirable. Working as we did with very large textual corpora and index files, a lot of effort was therefore devoted by Aviezri, his graduate students and the Respor team to text as well as files' and indexes' compression techniques. The results are reported in [15], [20], [21], [24], [26], [27], [28], and [29].

To sum up: full-text systems, their architecture and their efficient development; feedback systems in IR; natural language processing in IR; compression techniques; theoretical issues; legal information computerized systems; and, in a different context, Judaica studies, Responsa literature awareness and availability, all these and more were some of Aviezri's remarkable contributions to these fields.

We are all so thankful and grateful to him for that.

They shall still bear fruit in old age; they shall be fresh and flourishing.

Psalms 92, 14. [6]

[6]For at least 9 different translations of the Hebrew original of this verse, see
http://bible.gospelcom.net/bible?passage=PS+92&language=english&version=NIV&showfn=on&showxref=on

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