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Abdul Jerri

An appreciation on his seventy-seventh birthday

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It is unusual to celebrate a seventy-seventh birthday, but, after all, why not? Abdul Jerri is an unusual man, and we feel that now is an auspicious time to voice our appreciation of all he has done, and continues to do, for mathematics in the course of his busy, hard-working professional life. So this article is a 'thank–you' to Abdul: for his friendship and good company, for his contributions to mathematics, and for his founding and sound generalship of the journal Sampling Theory in Signal and Image Processing, an issue of which you are now reading.

Abdul Jabbar Hassoon Jerri was born in Iraq in 1932. He earned a B.Sc. in physics from the University of Baghdad in 1955 and then came to the USA for an M.Sc. in physics at the Illinois Institute of Technology. He finished his Ph.D. in mathematics at Oregon State University in 1967 where he was a student of William M. Stone. Over the years Abdul's wide-ranging research interests have been in integral and discrete transforms where he was an innovator of iterative methods for nonlinear problems, sampling expansions, the Gibbs phenomenon and operational sum methods for difference equations.

Abdul came to Clarkson University in 1967 as Assistant Professor of Mathematics, retiring as Professor Emeritus in 2002. During these years Abdul took up several visiting positions in middle-eastern countries, including Egypt, Kuwait, Oman, and Jordan. His fostering of links between east and west in this way has been a heroic endeavour; it is one of his major achievements and we salute him for it.

Abdul's Middle Eastern adventures had some dramatic moments; for example, he narrowly escaped the Iraqi invasion of Kuwait in 1990. The following note about this appears on the Acknowledgements page at the beginning of the book [5]. The Editor Robert J. Marks II says:

> A special commendation goes to Dr. Abdul J. Jerri. Dr. Jerri served as a visiting associate professor in Kuwait. He called me in Seattle from there and reported that his manuscript had been completed. Iraq invaded Kuwait the next day. After a number of days of uncertainty, he called again. He had escaped with only that which he could carry. We are thankful that one of the items he chose to carry was a hard copy of the chapter you see in this book.

This experience did not deter Abdul from his purposes in the Middle East, but once again he had a narrow escape. The year 2003 saw former President Bush's ultimatum to Saddam Hussein and the subsequent invasion of Iraq in March of that year, precipitating the Iraq War. Abdul was spending the academic year 2001–2002 as a Fulbright scholar at Yarmouk University in Jordan and had made a trip to Baghdad to visit relatives there. A day or so before the attack he knew that he must leave in a hurry and started to make his way back to Jordan by bus. There was some confusion though: the bus was not allowed to enter Jordan and people were crowded onto those buses that could make the journey. Sitting on the floor of a bus beside the driver did not make for a very dignified exit, but it really was in this manner that Abdul found his way back to Jordan.

Unfortunately, the emergency conditions forced Abdul to abandon many possessions including books and documents — the Kuwait experience again. The manuscript of " Integral and Discrete Transforms with Applications and Error Analysis " was one of the casualties; the book would have been lost altogether had not the publisher, Marcel–Dekker Inc., saved the day by holding what was then the only existing copy!

Abdul has been an enthusiastic supporter of the SampTA workshops since their inception in 1995 in Riga, Latvia, and has always been a reliable contributor. He has served on the Technical committee of every one of them. These SampTA workshops have honoured him as a birthday celebrant, they have heard him as a plenary speaker and in fact at one SampTA meeting (Loen, Norway, 1999) he contributed two papers, at another (Riga) a half-day Tutorial.

On excursion with old and new friends at SampTA09

PLB writes:

Abdul Jerri's survey paper [1977], the first major survey article covering the broad area of sampling, modestly entitled "A tutorial review" by him, can be regarded as the turning point between work in sampling in signal and image processing prior to and after 1975 or thereabouts, as carried out by electrical and communication engineers, as well as mathematicians. Claude Shannon's two papers of 1948 [8] and 1949 [9] can be said to mark the beginnings of wide-scale studies of sampling analysis, at least in the West. In fact, between 1950 and about 1975 at least 250 articles appeared in many engineering journals dealing with various aspects of sampling, written by some 175 different authors. During this period some 30 papers written by about 25 mathematicians (listed in [1, p. 29]) were published. In the first posterior period, from 1975 until 1991–1993, R.J. Marks II lists in [5] almost a thousand papers written by some 800 authors of all fields, the majority of which are devoted to sampling. Thus, since the appearance of Abdul's survey paper, in a period of 15 years alone, almost 750 further papers appeared, and it is the period when not only engineers but also mathematicians in ever increasing numbers turned to the field and made it so popular. No doubt this milestone paper of 1977, which appeared in a prominent IEEE journal by invitation, was instrumental in this process[1].

The group working on sampling at Aachen—its first representative being Wolfgang Splettstößer—began its studies in 1975, and, prompted by Abdul's 1977 survey paper, invited him to present a colloquium lecture in August 1978. He was on his way to spend two years at Kuwait University as Director of their Mathematics Graduate Program. While in Aachen he also met Dr. H.D. Lüke (1935–2005), Professor of Communication Engineering, Aachen's great exponent of sampling processes and initiator in 1975 of the famous Aachen Colloquia on signal processing, held regularly since then. In fact, he was invited to lecture at the Third Aachen Colloquium on Stochastic Signals conducted by Dr. H. Meyr, Professor of Control Engineering, held in October 1979 with 95 participants.

During the next decade, Abdul put a terrific amount of his huge energy into writing up two of his seven great books, *Introduction to integral equations with applications* [B 1] and *Integral and discrete transforms with applications and error analysis* [B 2], based on his research work in these areas.

During this time he was also Visiting Associate Professor at the American University in Cairo (1986–88) and again at Kuwait University as Associate Professor (1989–90).

Then we met Abdul again in January 8–11, 1992, when he lectured at the special session on "Interaction of Harmonic Analysis, Signal Processing and Computational Mathematics," conducted by Dr. Zuhair Nashed of the Univer-

[1]E. Meijering's history of interpolation theories [7], from ancient times to modern signal processing, lists 358 references; of these about 300 are devoted to the period 1915–2000, and 12 of its 20 text pages are devoted to this period; it begins with Whittaker's 1915 paper [11]

sity of Delaware during the AMS Annual Meeting, Baltimore, Maryland.

This special session, which was so successful on account of the timeliness and importance of the three themes it represented and the great interaction between them, included as invited speakers, as well as Abdul and myself, A. Aldroubi, G.A. Anastassiou, J.J. Benedetto, A. Boumenir, C. Brislawn, S.D. Casey, W. Dahmen, I. Daubechies, R.J.P. Figueiredo, S. Kadambe, J.D. Lafferty, W.R. Madych, Y.F. Meyer, H. Ogawa, M. Perlstadt, M.R. Razali, S. Saitoh, W. Schempp, K. Seip, H.S. Shapiro, G. Strang, G.G. Walter, G.L. Weiss, D.H. Wood, Xin Li, R.A. Zalik, and M. Zwaan.

It was the largest special session I ever attended and apparently the largest ever organized by the AMS (some 30 presentations with a session held each day of the meeting). The session was so heavily attended, as I recall, people standing even outside the wide open door, that an even larger room was organized for the next day. But Abdul and I managed to sit in the second row of the room and did enjoy the special session. It is such a pity that Zuhair had not planned the publication of a proceedings; it was actually a major symposium.

From Abdul's very interesting reports, communicated to two of us (PLB and MZN) at our hotel, concerning his external professorships in the Arab speaking world and the great success of the two books he had written and published, and five more that followed, we could now understand why we had heard little of him in matters sampling since about 2000.

In January 1994 the International Conference on "Mathematical Analysis, Wavelets, and Signal Processing" took place in the glorious ancient city of Cairo [6]; it was conducted by Mourad Ismail, Zuhair Nashed, Ahmed Zayed, and Ahmed Ghaleb, the occasion being Paul Butzer's 65th birthday. This conference, held under the auspices of the Mathematics Department of Cairo University and supported by the National Science Foundation (their SDCF Program), provided a unique forum for some 60 mathematicians and engineers representing 10 countries to exchange ideas and discuss new research trends. There again Abdul gave an invited lecture [1995a].

Our next joint get–together was at the "Workshop on Sampling Theory and its Applications," held in September 1995 at Jurmala on the Baltic Sea near Riga, Latvia, and conducted by I. Bilinskis (of the Institute of Electronics and Computer Science, Riga., General Chairman), G.D. Cain (vice-General Chairman) and F.A. Marvasti (Program Chairman). It was to be our First SampTA Workshop, held regularly every two years since then. There we had the pleasure to participate in Abdul's half-day tutorial on sampling [1995b]. During an extended walk on the golden sands of the Baltic sea the idea occurred to us that a journal representing our ideas of the broad area of sampling in signal and image processing would be needed. Naturally the ideal colleague for such a far-reaching and difficult project was our long-standing friend Abdul Jerri, who had dedicated at least 25 years of his life to the subject. Indeed, his very first publications ([1969a] and [1969b]) were papers on Kramer's generalization of the sampling theorem.

Further discussions about our new journal concerning its name, its scope etc., took place with many members of the present board of editors during the second SampTA Workshop held in June 1997 in the Departamento de Electrónica e Telecomunicações, Universidade de Aveiro, Portugal, and conducted this time by its present Chair-holder, Dr. Paulo J.S.G. Ferreira. This workshop was an exceptional blend of theoretical and mathematical aspects of sampling and engineering applications such as tomography, digital filtering, filter banks, array processing, and telecommunications. Paulo invited Abdul to give the first plenary talk on Gibbs' Phenomenon in sampling [1997]; this was most appropriate—the proceedings were dedicated to his 65th birthday.

In Aveiro Abdul invited Rolf Stens and one of us (PLB) to an exclusive dinner, where we were delighted to meet his wife Suad and 15–year old daughter Huda. Both of us experienced there the special harmony, the clear love that existed between the three.

Suad and Huda

Upon his return in 1998 from Sultan Qaboos University, Oman, where he had been a Fulbright scholar, Abdul spoke to one of us (PLB) in detail about the various periods he had spent at the universities in Cairo, Kuwait (and later Jordan), and it had always been his deep, sincere intent to do his very best to bring the teaching and research level there up to modern standards. He felt that in Oman, in particular, one did not seem to appreciate this fact. It did really hurt him.

Based on the discussions described above, Abdul finally decided to launch our own journal, "Sampling Theory in Signal and Image Processing–An International Journal", in 2000; the first issue appeared in January 2002.

A courageous decision and enterprise—what a great chance for our sampling community!

JRH writes:

I had known of Abdul Jerri's reputation long before 1994 but it was not until that year that we met, at the conference in Cairo already mentioned in glowing terms by PLB.

Most of the conference participants were staying at the Cairo Hilton. The university for which I worked for in those days would never have agreed to support my staying at such a grand hotel, so my wife and I, more than happy in our rôle as 'poor relations', were at a delightful small hotel 'round the corner'. It was here in the hotel breakfast room on the first morning of the conference that I recognized Abdul from the photograph appearing at the end of his big survey paper [1977]; and so began our long-standing friendship. How useful those IEEE photos are!

I think it would be interesting to touch now on just a few of the research topics that have interested Abdul during his professional life, and mention some of his many publications in these areas.

Abdul's interest in the sampling theory of band-limited functions is evident from the beginning of his scientific career. The topic hardly needs an introduction to the readership of this Journal; nevertheless, we can make a start by quoting everybody's classical point of reference in this field, the Sampling Theorem, stating that the functions f which are inverse Fourier transforms of those members of $L^2(\mathbb{R})$ that are null outside the interval $[-\pi, \pi]$ have a representation in terms of samples taken at the integers, a *sampling series* in fact:

$$f(t) = \sum_{n\in\mathbb{Z}} f(n)\,\frac{\sin \pi(t-n)}{\pi(t-n)}, \qquad (t \in \mathbb{R}).$$

A rough idea of why this should be true can be obtained by first expanding F in Fourier series:

$$F(\omega) = \frac{1}{\sqrt{2\pi}} \sum_{n\in\mathbb{Z}} c_n e^{-i\omega n};$$

then the coefficients c_n are given by

$$c_n = \frac{1}{\sqrt{2\pi}} \int_{-\pi}^{\pi} F(\omega) e^{i\omega n}\, d\omega = f(n).$$

The sampling series is obtained formally by multiplying this Fourier series by $e^{i\omega t}/\sqrt{2\pi}$ and integrating the result over $[-\pi, \pi]$.

The fact that the coefficient c_n is a sample of f arises from the fact that the Fourier kernel $e^{-i\omega t}/\sqrt{2\pi}$ has the property that when one of its arguments takes successively the values n, $(n \in \mathbb{Z})$, an orthonormal basis for $L^2(-\pi, \pi)$ results.

This viewpoint prompts the question as to whether there are other kernels, $K(\omega, t)$ say, with a similar property; that is, there is an associated set of points $\{t_n\}$ such that $\{K(\omega, t_n)\}$ is an orthonormal basis for some L^2 space, and whether a sampling series can be deduced.

The question goes back to a note by Weiss of 1957 [10], and was soon taken up in more detail by Kramer in 1959 [4]. Kramer found classes of such kernels associated with the eigenfunctions of certain differential operators.

For some years Kramer's paper attracted little attention except for one paper by Campbell in 1964 [2]. However, by the middle 1960s Abdul started to study the topic in earnest; these studies were well under way with his doctoral dissertation of 1967 "On extension of the generalized sampling theorem"[2].

Indeed his first three published papers, all dating from 1969, deal with aspects of *Kramer's generalized sampling theorem* (or sometimes just *Kramer's Lemma*) as it came to be known. These are the papers [1969a], [1969b], and [1969c].

In [1969c], for example, Abdul calculated certain sampling functions by specializing Kramer's theorem. Some cases he considers are the special functions of Laguerre, Gegenbauer, and Chebyshev, the spheroidal wave functions, and certain special functions associated with fourth order boundary value problems. The calculations are quite lengthy and involve a detailed knowledge of the theory of special functions. Whereas many authors would have stopped at this point, it is an excellent feature of Abdul's frame of mind that he goes on to mention specific applications in physics.

Kramer's sampling theorem is a topic that subsequently grew into a large research area which continues to attract attention. Many different sources for appropriate kernels have been identified and the topic has seen considerable further generalization, even reaching into the theory of reproducing kernels. Abdul was there at, or very near, the beginning and it is his good taste and judgment that have helped the topic to flourish.

Turning now to another topic, it says much for Abdul's resourcefulness as a mathematician that he was a pioneer in realising that any attempt to represent discontinuous functions by sampling series will inevitably give rise to the Gibbs 'overshoot' phenomenon, and that this overshooting cannot be reduced by merely increasing the sampling density. Several references to his work in this area will be found in the bibliography. Abdul himself felt it to be so important a topic as to justify two books on the subject ([B 4] and [B 5]), and it is an active area for research to this day as one may see in [3], for example.

Although Abdul's work has been mostly in classical analysis he has not neglected more modern developments. For example, he was quick to notice that the continuous wavelet transform of a function f, say $\mathcal{W}(a, b)$, where a is the scale parameter and b the translation parameter, can be represented as a sampling series; necessarily a double series because of the two degrees of freedom. Indeed, $\mathcal{W}(a, b)$ is sampled at the dyadic points $(2^{-j}, k2^{-j})$, $k, j \in \mathbb{Z}$. Abdul calculates

[2]A preliminary version had appeared in *Proc. SIAM Natnl. Meeting, Seattle, 1965*

the sampling functions explicitly in terms of the mother wavelet. This material appeared in [1995b].

Since it is impossible to go into a complete account of Abdul's work here, I have selected just one of his papers to look at in detail. This is the "rail track" paper [2001], presented to the SampTA meeting of that year in Florida, where the question is asked: "How should one space the cross-ties for a rail track ?"

I think this paper of Abdul's typifies his thoroughness of approach, it brings together several aspects of his previous work, and furthermore it is a striking example of sampling theory applied to a very down-to-earth problem which is not one of the usual applications in communications engineering. One has only to start reading it to get the feeling that, yes, this is the *right* way to go about a problem of this kind.

The rail track is modelled as an elastic beam on a non-elastic foundation. Clearly, its profile can be thought of as a function which is required to be kept in an identically zero state by ensuring that its samples, which are now the positions of the cross ties, are zero at suitably spaced points.

A. Wasiutynski's approximate criterion for the spacing S between the cross ties had been given in 1937; it is that S should satisfy

$$S \leq \frac{\pi}{4\beta},$$

where β is a constant depending on the parameters of the problem. The criterion was established partly on the basis of an already existing analysis of the continuous problem, and partly on results obtained by direct measurement.

Abdul gives a complete solution to this problem, finishing with a delightful little *coda* to the main theme. But more of that when we get there!

First, Abdul formulates the problem in terms of a fourth order non-linear boundary value problem in which the boundary conditions involve parameters representing the spring constant and the flexural rigidity of the system. When put into dimensionless form, the equation that must be solved takes the form

$$\frac{d^4y}{dx^4} = -y^n(x), \;\; 0 < x < \infty; \quad y(\infty) = y'(0) = y'''(\infty) = 0, \; y'''(0) = 1,$$

n being a parameter dictated by the spring constant of the problem; when $n = 1$ the boundary value problem is of course linear.

Abdul now takes up the linear case in detail. His method of solution is by Fourier cosine transformation together with a modified iterative method developed by himself and his colleagues in previous studies. It would be nice now to apply the sampling theorem to the solution and simply read off the Nyquist sampling rate. Unfortunately, matters are not quite that clear-cut. Although its Fourier transform decays rapidly, the solution is not in fact strictly band-limited. Abdul calls it "essentially band-limited" and notes that the approximate sampling theorem applies. This means that the solution can be written as the sum of two parts; the first being a sampling series for the solution constructed as if it were band-limited to $[-a, a]$ say, the second being an aliasing error term. This accounts for the error whose presence was recognised by Wasiutynski but which he declared to be "negligible."

After some calculation Abdul finds $Y_c(\lambda)$, the Fourier cosine transform of the (necessarily even) solution, to be $\frac{1}{1+\lambda^4}$. He finds that this gives

$$S \le \frac{\pi}{a\beta\sqrt{2}}\ .$$

The Wasiutynski condition is recovered when a is taken to be $2\sqrt{2}$, and in this case Abdul calculates the aliasing error numerically.

Broadly speaking, the same methods apply in the non-linear case. Abdul does not go into all the details here, but proposes that the use of Green's function for the integral representation of the non-linear problem followed by his modified iterative method will point the appropriate way forward.

Abdul calculates that a first approximation using these methods gives the sample point spacing estimate

$$S \le \frac{\pi}{a\beta\sqrt{2}\{y(0)\}^{(n-1)/4}}.$$

We come to the *coda* mentioned above. Abdul points out that the problem could be recast in polar co-ordinates, then the methods could be applied to the problem of supporting a thin tube by rings. The Hankel transform, evidently one of Abdul's favorites, would appear in place of the Fourier transform and the solution would appear in terms of Bessel functions. Abdul had already established the machinery to handle this case; it includes an appropriate form of his modified iterative method and an alising error associated with the Hankel transform.

Working midnight at SampTA09

MZN writes:

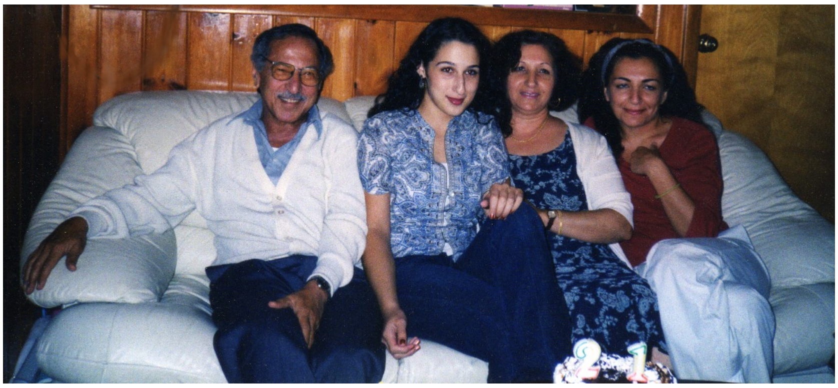
Abdul's first book was *Introduction to Integral Equations with Applications*, [B 1]. As an Executive Editor for this series I invited Abdul to submit his manuscript and read a good part of it. Abdul's goal is "to present the subject of integral equations, their varied applications, and basic methods of solutions on a level close to that of a first (sophomore) course in ordinary differential equations," with calculus and elementary differential equations as the only prerequisites. This is not an easy task, but Abdul was determined and he succeeded. The book has been used a textbook at several universities in North America and worldwide.

The book was dedicated "In memory of my father and my mother." In the Preface: "I owe my deepest appreciation to my wife, Suad, and to my family for their support and patience."

A second edition of the book (considerately expanded into 433 pages and containing material on integral transforms, numerical methods and many more applications and examples) was published in the prestigious series Wiley-Interscience Publication (John Wiley & Sons, 1999). A Student's Solutions Manual (with additional solved problems), to accompany the new edition was published by the author's new company "Sampling Publishing"! Recently Abdul received the copyright from Wiley and re-published a corrected version which is available from Sampling Publishing.

Abdul's second book is *Integral and Discrete Transforms with Applications and Error Analysis*, [B 2]. The book was dedicated "To my wife Suad, and the children, Saad, Iman, Nadia, Furat, and Huda."

In comparison with other books on transform methods, the book has added features of including the discrete Fourier transform along with a detailed analysis of its inherent errors, the applications to representing signals and systems, and an emphasis on how to choose the appropriate or "compatible transform for solving a boundary value problem."



Abdul, Huda, Suad and Nadia

Abdul's third book is *Linear Difference Equations with Discrete Transform Methods*, [B 3]. This time the dedication is "To my youngest daughter Huda." Abdul continued to extend his goal of presenting various subjects at an elementary level. The book covers the basic elements of difference equations and the tools of difference, sum calculus, and discrete transform methods for studying and solving, primarily, ordinary difference equations.

Abdul's fourth book is on a fascinating (but more specialized) research topic: *The Gibbs Phenomenon in Fourier Analysis, Splines and Wavelet Approximations*, [B 4]. This is the first book dedicated to covering the basic elements of the Gibbs phenomenon as it appears in various applications where functions with jump discontinuities are represented. The book combines detailed examples and illustrations combined with historical information. The author covers the appearance of Gibbs phenomenon in Fourier analysis, orthogonal expansions, integral transforms, splines and wavelet approximations. Methods for reducing, or filtering out, such phenomena in all of these function representations are also addressed. The book includes a thorough bibliography of 350 references.

Two other books have recently been completed and are soon to go to the press. *Advances in Gibbs Phenomenon* [B 5] is an edited collection of papers by major contributors to the subject, invited by Abdul, who has also contributed three long introductory chapters in this collection.

On June 4, 2009, I received from Abdul a draft copy of his manuscript entitled *Wavelets, Detailed Treatment with Basic Fourier Analysis*, [B 6]. The cover letter that was sent with the manuscript carries the excitement: "Finally, I have the simplest wavelets book. I am enclosing the final draft, and I would appreciate your general opinion or review." This is a project that Abdul has been working on for over seven years. Again his goal is to make this material accessible to undergraduate students. To quote from the Preface: "This book represents an attempt to present the most basic concepts of wavelet analysis, in addition to the most relevant applications. Compared to the half a dozen or so introductory books on the subject, this book is designed, with its very detailed treatment, to serve the undergraduates and newcomers to the subject, assuming a general calculus preparation and what comes with it of matrix computations. The essential subjects needed for wavelet analysis, namely vector spaces, and Fourier series and integrals, are presented in a simple way to suit such a background. It is a challenging task, and the book is an attempt at meeting such a challenge." The "Acknowledgments" are yet to be written, but the dedication has been written: "In loving memory of my beloved wife Suad."

Abdul is always generous in acknowledging colleagues and students for suggestions and support. In his first book he thanked me "for valuable advice and for encouraging this project." I am thanked in the Preface of almost all his books "for encouraging the project all along and for very valuable suggestions."

On a different subject, I would like to say that my small excursion into sampling theory came by way of my interest in inverse and ill-posed problems, and reproducing kernel spaces. I was very much inspired by conversations with PLB and Abdul during my visits to Aachen and Potsdam, and meetings elsewhere, and particularly by reading some of their papers and papers by JRH. So this is a perfect place to express my appreciation.

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