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Editorial

Foreword to the proceedings of the OrthoQuad 2014 conference

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ABSTRACT

OrthoQuad 2014 was an international symposium on orthogonality, quadrature, and related topics, held on January 20–24, 2014 in Puerto de la Cruz, Tenerife, Spain. It was held in memory of Professor Pablo González-Vera (1955–2012).

1. A short CV of Pablo González-Vera

Pablo González-Vera was born in Vallehermoso (La Gomera, Canary Islands) on January 25, 1955. He studied Mathematics at University of La Laguna (1974–79), and began teaching at this university in 1980 and became *Cátedratico (Full Professor) de Matemática Aplicada* in 1992.

He started his research in rational interpolation and Padé approximation, in collaboration with Professor Luis Casasús (now in Universidad Politécnica de Madrid) [1,3]. In particular Padé-type and two-point Padé approximation got his specific interest [4–7,9–14,20].

This resulted in a Doctoral Dissertation on Two-point Padé Approximation [8] that he defended in 1985 at the University of La Laguna. His supervisor was Professor Nácere E. Hayek Calil.

But soon orthogonality of the denominator polynomials of the approximants and Laurent polynomials got his interest and these showed up in another application, which became his most favored topic: numerical quadrature [2,15,17–20,16].

That was the germ of a research group on Approximation Theory in University of La Laguna. From 1991 on, eight doctoral thesis on Orthogonality and/or Quadrature were supervised by González-Vera, with the most recent being defended shortly after his passing away.

Since 1989 a collaboration of the “gang of four” started: Adhemar Bultheel (KU Leuven, Belgium), Erik Hendriksen (University of Amsterdam, The Netherlands) and Olav Njåstad (University of Trondheim, Norway). In 1990 a local report of 84 pages [21] was published that formed the embryo of what became ten years later their book *Orthogonal Rational Functions* (Cambridge University Press, 1999) [110].

During these ten years they collaborated intensively on the properties of these rational functions that generalized the orthogonal polynomials and Laurent polynomials. The support of the orthogonality measure could be the unit circle or

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on the real line (the whole real half line, the half line or a finite interval). They appeared in multipoint versions of Padé approximation, in generalizations of classical moment problems, and in quadrature formulas on the real line or the unit circle to generalize Gauss and Szegő numerical integration methods. [37,38,46–49,61,62,66–73,81–83,87,88,96–99,102–105,108,109]. Their investigations were deepened further in the subsequent period [117–119,126–128,132,138–140,142,145,154,164,173–175,179,183].

With his Ph.D. students he started several parallel research topics like Laurent Padé and Padé-type approximation (M. Camacho, Ph.D. 1991) [51,52,74,100,101], multipoint Padé-type approximation and quadrature (M. Jiménez Paíz, Ph.D. 1991) [15,27,30,32,41,64,80,90,112,115], multivariate Padé approximation (R. Orive, Ph.D. 1991), [42,59,60] composite and alternative numerical quadrature formulas (J.C. Santos León, Ph.D. 1995) [19,29,43,44,57,63,65,85,91–93], Convergence of two-point Padé-type approximants (C. Díaz Mendoza, Ph.D. 2000) [89,94,107,114,116,130,137,144,149,151,152,170], quadrature on the unit circle (L. Daruis, Ph.D. 2001) [113,121–123,125,129,134–136,143,146,156,158,159,167] which resulted in their book *Ortogonalidad y Cuadraturas sobre la Circunferencia Unidad* [153], orthogonal Laurent polynomials and quadrature on the unit circle and on the real line (R. Cruz Barroso, Ph.D. 2007) and (F. Perdomo Pío, Ph.D. 2013) [133,141,146–148,155,158–160,165,166,168,169,171,172,176,180,181,184].

For completeness we mention all Pablo's other publications that were not mentioned so far [22–26,28,31,33–36,39,40,45,50,53–56,58,75–79,84,86,95,106,111,120,124,131,150,157,161–163,177,178,182,185].

Besides his scientific career, Pablo was also engaged in the organization of the University of La Laguna. He was director and secretary of the Department of Mathematical Analysis and dean of the Faculty of Mathematics, in the period from 1992 to 2000, and Vice Chancellor for Planning and Infrastructure during the 4 years 2007–2011.

Pablo died on July 11, 2012 at the age of 57. He was not only a well recognized mathematician but a remarkable human being. He was extremely modest, friendly, concerned, and had a warm relation with all the people that surrounded him. No wonder he has left a large number of friends and colleagues in Spain and abroad who miss him dearly.

2. The orthoQuad 2014 conference

The conference in honor of Professor González-Vera took place in Puerto de la Cruz, Tenerife, Spain on 20–24 January 2014.

There were 109 registered participants from 24 different countries. Besides 11 plenary lectures also 36 short lectures and 16 posters were presented. In a special session on *Mathematics: Theory and Applications* 8 more short lectures were presented on general mathematical topics.

The organizing Committee consisted of R. Orive (Chair), M. Camacho, R. Cruz-Barroso, C. Díaz-Mendoza, C. González, M. Jiménez-Paiz, F. Perdomo Pío, F. Pérez, H. Pijeira, J.C. Santos-León, J. Trujillo.

The Scientific Committee was A. Bultheel (Chair), G. López-Lagomasino, F. Marcellán, O. Njåstad, R. Orive.

3. A survey of the contents

Some of the contributions at the conference can be found in these proceedings. They are all related to the work of Pablo and cover almost completely the spectrum of topics he has been involved with.

We find Padé approximation and rational interpolation with some variation in several of the papers. In [P6] we find a barycentric representation of the Padé approximants and stable ways to compute them.

A multipoint generalization of the classical Padé approximation is treated in [P12] where the convergence and zero distribution of rows in the table of approximations are investigated.

Another generalization is Hermite–Padé approximation where a vector of Laurent series is simultaneously approximated by a vector of rational approximants with a common denominator (Type II) or one tries to make a polynomial combination of the series look like a polynomial (Type I).

More precisely, Type I comes in the form $\sum_{i=1}^{m}[p_{\vec{n},i}(z)f_i(z)] - q_{\vec{n}}(z) = O(z^{-|\vec{n}|})$ where the f_i are power series in z^{-1} and the $p_{\vec{n},i}$ and $q_{\vec{n}}$ are polynomials of appropriate degree. In [P16] the asymptotics of Type I approximants are investigated when the series are rational modifications of a Nikishin system.

In Type II problems, one investigates the system $q_{\vec{n}}(z)f_i(z) - p_{\vec{n},i}(z) = O(z^{-(n_i+1)})$, $i = 1, \dots, m$. The asymptotics of these approximants, in the case of two analytic functions f_i with branch points, depends on an algebraic function of order three which is investigated in [P3]. For a related problem on the unit circle see [P9] below.

Uniform convergence of Hermite and Hermite–Fejér interpolants but now by Laurent polynomials in equidistant points on the unit circle with interpolation conditions up to the second derivative is proved in [P5].

Orthogonal polynomials and recurrence relations are represented by several of the papers. In [P13] Minkowski's question mark function is used to define the orthogonality. Since it is fractal, there is no analytic expression for it. Therefore the behavior of the coefficients in the three-term recurrence relation needs a numerical approach.

Multiple orthogonal polynomials are related to Hermite–Padé approximation. The type II polynomials appear in vectors that are simultaneously orthogonal to a vector of measures. For the case of two measures on the unit circle their determinant formula and the recurrence relation are studied in [P9].

The relation between different orthogonal polynomial sequences (OPS) is the subject of two papers [P4, P2]. Since the OPS form a basis for the polynomials, it is possible to express an orthogonal polynomial of the first OPS in terms of the second OPS.

This is the connection problem. Two approaches for finding the connection coefficients in the case of bivariate Krawtchouk polynomials can be found in [P4]. A more complicated connection between two OPS can involve a relation between their differences. A linear combination of differences of the first OPS can be equal to a linear combination of differences of the second OPS. This coefficient problem is discussed in [P2] both for a continuous and a discrete variable. It is also applied to Sobolev orthogonality.

The bivariate Krawtchouk polynomials are used in [P19] to obtain a least squares approximation of an image which can be used to detect the edges of the image.

More discrete OPS and their differences are discussed in [P17]. The Δ-Meixner–Sobolev orthogonal polynomials are orthogonal with respect to the Pascal distribution in a discrete Sobolev type inner product. A Mehler–Heine formula expressing the asymptotic behavior of the polynomials is proved and some consequences for their zeros are obtained.

An OPS when the orthogonality measure is complex and the path of integration can be any path in the complex plane appears in the convergence study of Padé approximation, but they were also applied in the Riemann–Hilbert approach to random matrices. The asymptotic zero distribution of such OPS is the subject of [P1]. In particular their phase transition in the case of a standard cubic model for non-Hermitian orthogonal polynomials.

Orthogonality with respect to a Sobolev inner product was already present in the papers [P2, P17] and bivariate OPS appeared in [P4] mentioned above, but both aspects also appear in the contribution [P15]. Product domains with their natural Sobolev orthogonality over the product of the weight functions is investigated. Examples are given for Laguerre and Gegenbauer cases.

Further applications of OPS appear in the papers [P11, P20]. In [P11] the OPS is applied in a physical context. Different complexity measures are defined that are information theoretic measures expressing the spread of the Rakhmanov probability density $\rho_n(x) = \omega(x)p_n^2(x)$ of the OPS $p_n(x)$ orthogonal with respect to the weight function $\omega(x)$. The case of Hermite, Laguerre, and Jacobi OPS are investigated and it is shown how they depend on n.

In [P20] the recurrence for OPS supported on the positive real line is applied in birth and death processes. Conditions on the recurrence coefficients should predict whether the smallest points in the spectrum are positive and for the support to be discrete without a finite limit point.

Of course numerical quadrature is a major application of OPS and this subject was dear to the heart of Pablo.

The Radau and Lobatto quadrature formulas are the subject of [P10]. These fix one or two nodes in advance and choose the other nodes and the (positive) weights to obtain maximal algebraic exactness. The relation between orthogonality on the interval $[-1, 1]$ and orthogonality on the unit circle is especially simple when the measure on the circle is symmetric. That is exploited to obtain conditions for quadrature formulas with positive coefficients of the Radau and Lobatto type.

The same type of quadratures are discussed in [P14] for the case of strong Stieltjes distributions on an interval (a, b), $0 \leq a < b \leq \infty$, but this time based on orthogonal Laurent polynomials rather than OPS, where the order in which positive or negative powers of the variable are added to the Laurent polynomial subspaces is arbitrary. This is probably the last paper to be published with Pablo as a co-author.

An anti-Gauss formula is an $(n+1)$-point formula that has the same error as an n-point Gauss formula but with opposite sign. This can be used to estimate or eliminate the integration error. In [P18] this idea is generalized to $(n+k)$-point formulas with the same property for the error which now should hold for all polynomials up to degree $n + 2k - 1$, $k \geq 1$, instead of the previously known case where k was only equal to 1.

The multipoint generalizations of the orthogonal polynomials are the orthogonal rational functions with the orthogonal Laurent polynomials as a special two-point case. Both the orthogonal rational functions and the Laurent polynomials appear in the matrix approach to quadrature that is used in [P7]. It is shown how to compute the nodes and weights of the quadrature formula by solving (generalized) eigenvalue problems for structured matrices.

A final application of the orthogonal rational functions can be found in [P8] where the associated multipoint moment problem on the real line is considered. In the indeterminate case there are infinitely many solutions to the moment problem, which can all be characterized by a Nevanlinna parameterization. That is a linear fractional transform of the set of Pick functions, defined by 4 functions. The paper analyzes the asymptotic behavior of these four functions.

4. The contributions

P1. Phase structure and asymptotic zero densities of orthogonal polynomials in the cubic model
G. Álvarez, L. Martínez Alonso, E. Medina

P2. On linearly related sequences of difference derivatives of discrete orthogonal polynomials
R. Álvarez-Nodarse, J.C. Petronilho, N.C. Pinzón-Cortés, R. Sevinik-Adiguzel

P3. Hyperelliptic uniformization of algebraic curves of the third order
A.I. Aptekarev, D.N. Toulyakov, W. Van Assche

P4. Bivariate Krawtchouk polynomials: Inversion and connection problems with the NAVIMA algorithm
I. Área, E. Godoy, J. Rodal, A. Ronveaux, A. Zarzo

P5. Convergence of Hermite interpolants on the circle using two derivatives
E. Berriochoa, A. Cachafeiro, J. Díaz

P6. New representations of Padé, Padé-type, and partial Padé approximants
C. Brezinski, M. Redivo-Zaglia

P7. Matrix methods for quadrature formulas on the unit circle. A survey
A. Bultheel, M.J. Cantero, R. Cruz-Barroso
P8. Holomorphic functions associated with indeterminate rational moment problems
A. Bultheel, E. Hendriksen, O. Njåstad
P9. Multiple orthogonal polynomials on the unit circle. Normality and recurrence relations
R. Cruz-Barroso, C. Díaz-Mendoza, R. Orive
P10. A connection between Szegő-Lobatto and quasi Gauss-type quadrature formulas
R. Cruz-Barroso, C. Díaz-Mendoza, F. Perdomo Pío
P11. Complexity analysis of hypergeometric orthogonal polynomials
J.S. Dehesa, A. Guerrero, P. Sánchez-Moreno
P12. Rate of convergence of row sequences of multipoint Padé approximants
B. de la Calle Ysern, J. Mínguez Ceniceros
P13. Orthogonal polynomials for Minkowski's question mark function
Z. Dresse, W. Van Assche
P14. Radau and Lobatto-type quadratures associated with strong Stieltjes distributions
C. Díaz-Mendoza, P. González Vera, M. Jiménez Paíz, O. Njåstad
P15. Sobolev orthogonal polynomials on product domains
L. Fernández, F. Marcellán, T.E. Pérez, M.A. Piñar, Y. Xu
P16. On the convergence of type I Hermite–Padé approximants for rational perturbations of a Nikishin system
G. López Lagomassino, S. Medina Peralta
P17. Δ-Meixner–Sobolev orthogonal polynomials: Mehler-Heine type formula and zeros
J.J. Moreno-Balcázar
P18. Generalized anti-Gauss quadrature rules
M. Pranić, L. Reichel
P19. Edge detection based on Krawtchouk polynomials
R. Rivero Castillo, H. Pijeira Cabrera, P. Amado Assunçao
P20. Spectral properties of birth–death polynomials
E.A. van Doorn

Pablo González-Vera (1955–2012)

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