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Annie@60: A Life in Approximation

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At the 4th Dolomites Workshop on Constructive Approximation and Applications, September 8–13, 2016, we had the honour of celebrating the lifetime career achievements of Professor Annie Cuyt of the University of Antwerp in Belgium. Born on May 27, 1956[1], Annie celebrated her 60th birthday earlier in the year. With everyone in attendance skilled in the art of approximation, however, there was no objection to a half percent error and the birthdate was reset to September 9 and celebrated[2] as such.

To give an overview of Annie's body of work is no simple task. With more than 100 published papers, 3 books, 5 patents, more than 50 co-authors, and contributions to many diverse areas, this is a task better suited to a committee[3] than a single person. To elaborate on the diversity of Annie's contributions: her profile page on `MathSciNet` lists no fewer than 13 areas, ranging from the theoretical (approximation and expansion, numerical analysis, integral transforms and operational calculus) to the practical (information and communication, circuits, systems theory and control).

From an early age Annie realised that mathematics would be her life. It is therefore no surprise that her first paper appeared when she was barely out of her teenage years. This was on a topic that requires no small amount of mathematical maturity, namely abstract Padé approximants in operator theory [1]. Not long after she published her first book [113], which was based on her doctoral thesis. The paper [1] drew the following remark in Mathematical Reviews "The paper under review gives a clear and careful account of this theory...". The words "clear and careful" were to remain descriptive of her work throughout her career.

The outstanding achievement of Annie's early career, and arguably her entire career, was her work on multivariate Padé approximation. In the single variable case the definition of a Padé approximant does not leave much freedom, but this is not the case when working with two or more variables. There are definitions by Arioka, Brezinski, Chisholm, de Bruin (the alphabetical list continues and so does the list of definitions). While most of these authors approached this theory from a lattice space angle, Annie considered this from a homogeneous viewpoint. Himself a major contributor to this field, Claude Brezinski remarks on her definition "She gave another, which is maybe the best one."

One advantage of the homogeneous approach is that the approximants have stronger projection properties than those generated by other definitions [62]. In addition, these approximants inherit many beautiful properties from the univariate case, namely structured linear systems for their computation [8, 81], an epsilon-like algorithm for their recursive generation [3, 9], a qd-like algorithm [12, 14], and their univariate-like relationship to some multivariate orthogonal polynomials [65, 97].

Switching with ease between the tools of algebra and of analysis, Annie then tackled the difficult problem of proving convergence of multivariate Padé approximants. This resulted in an extension of the well-known de Montessus de Ballore theorem of the univariate case to the multivariate case [39, 57]. Co-author Doron Lubinsky remarks "The multivariate case is quite complicated because of the complicated nature of singularities of multivariate functions, and also the decisions to be taken how to define the approximants. Annie's result is a fundamental and definitive contribution to a complicated topic."

Showing her versatility once more, Annie then branched into other parts of numerical mathematics and computer science. Triggered by a new course she was developing for the program in computer science at Antwerp, the idiosyncrasies of floating-point arithmetic became a focal point. With students and colleagues she wrote papers on catastrophic cancellation [68] and underflow [71], and put forward a constructive criticism of the C/C++ proposal for complex arithmetic [76].

On the more classical side of numerical analysis Annie made fundamental contributions to Gaussian cubature [65, 97] and Lebesgue constants for rational interpolation [100, 111]. In this area, a paper on some convergence results concerning certain columns in the qd-algorithm that were overlooked for 50 years is one that Annie is particularly proud of [92].

Arguably the most ambitious project of Annie's career was the monumental *Handbook of Continued Fractions for Special Functions* [114]. Her team of Belgian and Norwegian collaborators got together in various places around the world to complete this encyclopedic treatise on the classical special functions and their continued fraction expansions. Not only did these visits allow the authors to work free of the distractions of their home departments, but the host institutions benefited greatly from having such a powerful team on site.[4]

Where many books on special functions end up being a collection of formulas and theorems, the *Handbook* goes further by also providing software, either as a Maple package or via a web-based interface.[5] Furthermore, through skilled manipulation of the error terms in the continued fractions, validated results to any specified number of specified digits can be provided. Few software libraries for special functions can make that claim.

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[1]Born in Lubumbashi, at the time called Elisabethville, in the former Belgian colony of the Congo.

[2]A word of thanks to the Antwerp contingent, who complemented these celebrations with a tasting of some beautiful Belgian brews.

[3]The author thanks Claude Brezinski, Doron Lubinsky and Walter Van Assche for their input.

[4]Stellenbosch was fortunate to be a host in 2005, so I speak from experience.

[5]`http://cfsf.uantwerpen.be/`

In recent years Annie's research has returned to her roots of rational approximation, specifically from the viewpoint of sparse interpolation [98, 110]. At the Dolomites meeting there was a special session on this topic, with active discussion from many participants. Some of these talks can be found elsewhere in the present volume.

Walter Van Assche, a fellow Belgian mathematician, summarises her research contribution thus: "Flanders, and in particular the University of Antwerp, must be proud to have a performing research group in computational mathematics, with important classical themes such as continued fractions, Padé approximation, nonlinear approximation, all achieved through excellent research and management of Annie."

Annie's talents as researcher are equalled, if not surpassed, by her leadership and organizational qualities. Particularly active as a conference and workshop organizer, she was in charge of Dagstuhl (Germany), Banff–Oaxaca (Mexico), and Woudschoten (The Netherlands), all very prestigious international workshops. These were preceded by a very successful series of international conferences on approximation theory at her home university in Antwerp. In addition, her résumé reveals an impressive collection of scientific committees that she served on. This includes service to various Flemish and Dutch scientific bodies such as science foundations, supercomputing centers, and research foundations.

Accolades for Annie's scientific contributions are too many to mention: more than 100 invitations as plenary speaker to conferences the world over, research funding for a total of about 1200 person months and an additional 6.8 million euro for operations and equipment, a Fellowship from the Alexander von Humboldt Stiftung, the list goes on. But perhaps the most impressive among these is Annie's election as Lifetime Member of the *Royal Flemish Academy of Belgium for the Sciences and the Arts*, a singular honour from such an esteemed society.

Moving discontinuously from the sublime to the trivial, at celebrations like these it seems customary to offer a limerick. In conclusion, here is my effort:[6]

There was a young lady quite rational
Her approximants totally maximal
She continued each fraction
And Padé'd with passion
Till her fame reached far wider than national!

Annie $\in (0, 60)$

Journal publications and books of Annie Cuyt (to 2016)

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[6] In truth, two colleagues helped. But any transgression of official limerick meter is my own.

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