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Preface

This special issue of Linear Algebra and its Applications is dedicated to Paul A. Fuhrmann, in recognition of his long standing contributions and service to the field of Linear Algebra. While Paul's work has been mainly focused on developing the rich interconnections between Linear System Theory and Operator Theory, he never lost contact to Linear Algebra and its Applications, with major contributions to, e.g., Bezoutians, Hankel norm approximation, balanced realizations and model reduction, spectral factorization, inner functions, and the structure theory of linear systems. When Paul joined the Editorial Board of LAA, the two fields of Linear Algebra and Linear System Theory were quite separate and interaction was minor. Today, the situation has changed and mutual cross-fertilizations between these areas are evident and have become increasingly important. It was Paul Fuhrmann, both as a scholar and a researcher, who had a major and crucial impact on this healthy development. It has been therefore a great pleasure and privilege to the associate editors to compile this special issue in honor of Paul's outstanding achievements. The wide range of topics discussed in this issue clearly reflect the broad range of Paul's own research interests, including contributions to e.g. Nevanlinna–Pick interpolation, lossless and passive system, model reduction, observer theory, stochastic processes and LQG control, convolutional codes, factorization theory, state space realizations and behavior theory. In preparing this preface, we took advantage of Michiel Hazewinkel's unpublished notes "Believing in Polynomials", delivered at an after dinner speech in Kaiserslautern, 1997, on the occasion of Paul's 60th birthday.

1. The early phase

Paul Abraham Fuhrmann was born in Zagreb, former Jugoslavia, in 1937. The second world war and the Nazi occupation in Jugoslavia forced him to escape from the country under exceptional circumstances. It is not the proper place here to review his convoluted family history during that dark period. Suffice it to say, he finally arrived in 1945 in Israel. In 1958, he began to study Mathematics at the Hebrew University in Jerusalem where he received his M.Sc. degree in 1963. Two important teachers during that period were S. Agmon and S.R. Foguel. In 1963, he moved to Columbia University as a Ph.D. student. At that time, a number of eminent functional analysts passed through New York; one of them was Bella Sz.-Nagy, who lectured on his recent joint work with Ciprian Foias on contractions. This work had a great deal of influence on Paul's future work. Paul's Ph.D. supervisor was E.R. Lorch. However, in the critical year during which he was

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working on his thesis, Lorch went on sabbatical. Thus Peter D. Lax, who was at NYU, took over the supervision and in this way Paul got first hand access to the Lax–Phillips scattering manuscript. Lax suggested one problem to work on, but instead, Paul got more interested in deriving a spectral mapping theorem for the Sz.-Nagy–Foias functional calculus, which he achieved, using the just "out of the oven" corona theorem result of Carleson. By a lucky coincidence, Paul became aware of this result through a seminar on complex analysis run at Columbia University by Lipman Bers. This shows how randomness can influence the progress one's Ph.D. In 1967 he received his Ph.D.

2. Postdoc period

Between 1967 and 1972 he returned to Israel, as a lecturer in mathematics at Tel Aviv University. During that period his appetite for system theory awoke, being exposed to the work of Kalman through the book by Kalman, Arbib and Falb. An invitation by Roger Brockett to Harvard followed, which Paul accepted. He stayed there between 1972 and 1974. This was at the very beginning of the "golden age in control", and a very fruitful one for Paul, too, as most of the latter leaders of the field happened to pass through Harvard and the MIT. At this stage his work was oriented towards infinite dimensional problems. Joint papers with John Baras and Roger Brockett followed and showed the early interest of control theorists in advanced functional analytic methods. After this postdoc period he returned to Israel; since 1974 he has been with the Ben Gurion University of the Negev, first as senior lecturer and later as professor. Since 1990 he held the Earl Katz family chair in algebraic system theory, till his retirement in 2006. When moving to Ben Gurion University, his research shifted into a more algebraic direction. The first indication of this was his Journal of Franklin Institute paper that applied functional analytic and operator theoretic tools in an algebraic, finite dimensional context. This line of research, because of its power and elegance, soon became an addiction for Paul.

3. Research contributions

In bare numbers, his Curriculum Vitae lists over 100 publications in operator theory, linear systems theory and linear algebra. Famous among journal editors are his somewhat longer papers; some 60–100 pages long. His main scientific theme has been functional or polynomial models; he first learned about them at Columbia, within the context of the newly developed Sz.-Nagy–Foias theory. The starting point here is Rota's representation theorem of finite dimensional linear operators, which states that any such linear operator can be regarded as the restriction of the backward shift to a shift invariant subspace on the set of strictly proper Laurent series. One of Paul's great insight was to realize that this shift representation of linear operators can be developed into a powerful bridge between linear systems and linear algebra via polynomial models. The unifying power of polynomial models to linear algebra has been demonstrated in a series of his papers, leading e.g. to elegant proofs of the representation theorems of Ptak and Kravitsky for Bezoutians, the inversion theorem of Lander on finite Hankel matrices and the Gohberg–Semencul formulas. A key result by Paul is his celebrated shift realization theorem, which defines a state space representation for systems of higher order differential equations, directly in terms of the shift realization. In system theory it enabled him to develop a far reaching synthesis of Kalman's module theoretic approach to the realization problem, state space models and coupled higher order systems of differential equations. More recently, it enabled him to develop a polynomial model approach to Jan C. Willems' theory of behaviors, and thus to a far reaching generalization of singular systems of differential or difference equations. Polynomial models also led to a very astonishing approach to the celebrated Adamyan–Arov–Krein (AAK) theory for rational Hankel norm approximation.

His elegant textbook "Linear Systems and Operators in a Hilbert Space" established the basic relations between operator theory and linear systems in a novel and general way. The connections to linear algebra are further outlined in his textbook "A Polynomial Approach to Linear Algebra", that introduces the first and second year linear algebra material in a systematic and very efficient way, using the shift operator. It also contains in a very accessible and integrated form the basics of linear system theory, up to the AAK theory. Paul's philosophy towards research may be paraphrased as "forest before trees", without sacrificing computations, and is most clearly expressed in his preface to this book.

> "Basically, the approach taken in this book is a variation on the study of a linear transformation via a study of the module structure induced by it over the ring of polynomials. While module theory provides great elegance, it is also difficult to grasp for a student. Furthermore, it seems so far removed from computation. Matrix theory seems to be at the other extreme; it is concerned too much with computation and not enough with structure. Functional models, especially the polynomial models, lie on an intermediate level of abstraction between module theory and matrix theory."

During more than 40 years of mathematical research, Paul has combined mathematical literacy with truly remarkable computational abilities. But describing a complex person as Paul solely in terms of his research and academic achievements is grossly misleading. In addition to his love for research, he shares many other interests; be them in cultural activities as art, music, or good cooking, or even Israeli politics. The center of his life is his widespread family, his beloved wife Nilly, his three children Amir, Galid and Oded, his seven recent grand children Shaul, Naomi, Adam, Iddo, Gilad, Daniel and Noga and relatives. He has been always generous and supportive to students and colleagues alike (e.g. like us); but also stands up for an argument, whenever he believes that something has been untruly or misleadingly stated. Keywords that describe his character are: "honesty, friendship, love and care". But equally true for all of us is:

"It is impossible to spend a dull moment with Paul."

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V. Vinnikov
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