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Biography

A linear algebra biography

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ABSTRACT

In my talk at the LAA meeting in honor of Hans Schneider, I gave a brief biography of my introduction to linear algebra and my interaction with some of the linear algebraists at that time. It was suggested that I write this up, and thus the following.

I entered CCNY (College of the City of New York and later CUNY, City University of New York) in 1941. The war was on and math majors were being recruited by the US Army Air Force to become meteorologists. I enlisted and was sent to MIT. The Army permitted me to sit in on MIT math classes. (Two of the instructors were Norman Levinson and Robert Cameron.) After graduation I was stationed at different airports where I served as the weather officer. I was discharged in 1946 and returned to CCNY, where I took courses with Emil Post (of Post Logic) and Bennington Gill, and graduated with a B.S. degree in 1947.

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My next move was to the newly formed department of statistics at Columbia. The faculty consisted of Abraham Wald, Jacob Wolfowitz, Theodore Anderson, and Howard Levene. My linear algebra connection was in a basic course taught by Howard Levi that was based on Maxime Bôcher's 1907 book, *Introduction to Higher Algebra* [4]. There is a very interesting review of this book by Robert Thompson (1984), seventy-five years later. I can't remember whether Paul Halmos' *Finite-Dimensional Vector Spaces* of 1942 [7] was required or just recommended.

Harold Hotelling, well known in both economics and statistics, was at Columbia from 1931 to 1946, when he left for Chapel Hill to chair a new department of theoretical statistics. He is the originator of principal components (1933), canonical correlations (1936), and a number of important results in multivariate analysis and matrix calculations (1943). He suggested using powers of matrices to more readily estimate the largest eigenvalue. These papers were important not only for the theory but because they set the tone for mathematical statistics. The methods proposed by Hotelling are currently central in the data mining and machine learning literature.

I wanted to study with Hotelling, so applied for admission, was awarded a Rockefeller fellowship, and arrived at UNC in 1948. My first encounter with linear algebra was a course by Alfred Brauer, who was working on Gershgorin disc inequalities and ovals of Cassini. Emilie Haynsworth was in that class and continued her studies with him. Later on Tom Markham was also a student of Brauer; I am sure there were others, but I did not meet them. Brauer was of the old school, totally absorbed with mathematics. He was gentle with his students and they were attracted to him. My wife and I were invited to his house where we met his wife Hilda. After his death I visited her whenever I was in Chapel Hill. Alfred occasionally talked about his brother Richard, who was on the Harvard faculty and very well known. I also met Richard's son George, who is also a mathematician, at the University of Minnesota.

Brauer introduced me to E.T. Browne, another linear algebra faculty member. Browne was not well at the time, so I did not interact much with him. He published several papers from 1928 to 1930 and also a book on linear algebra. One of the papers was on the polar decomposition, another on the interlacing property of eigenvalues; he also showed that $\max_i \mathcal{R}\lambda_i(A) \leq \max_i \lambda_i((A+A^*)/2)$ and that $|\lambda_1(A)| \leq \sigma_1(A)$. Here λ_1 is the eigenvalue with largest modulus, and σ_1 is the largest singular value. Both of these inequalities were later generalized to majorization inequalities.

In addition to Hotelling, Pao-Lu Hsu was on the faculty. There were three Chinese mathematicians, all born in the same year, who changed the course of mathematics in China: Pao-Lu Hsu in probability and statistics, Lo-Keng Hua in functional analysis, and Shiing-Shen Chern in geometry. (For a review of Hsu's contributions see [5].) In 1949 Hsu was on sabbatical leave in China and decided to stay there. He wanted to help China build its mathematical and statistical base. As a result I couldn't take his course. Hotelling suggested that I study notes taken by students in the previous year and then give a lecture on what I had learned. Hsu's proofs were elegant examples of the use of linear algebra in statistics. My thesis in 1951 came out of these lectures and was on