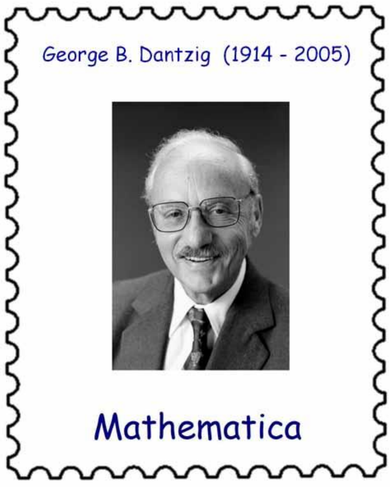
George Bernard Dantzig (August 11, 1914 – May 13, 2005)

by Heinz Klaus Strick, Germany



(photo by courtesy of Ed Souza / Stanford News Service)

The following episode is not a fictional story – it actually happened:

In 1939 when George Bernard Dantzig, a doctoral student at the *University of California* at Berkeley, was a few minutes late for the statistics lecture of his doctoral supervisor Jerzy Neyman. There were two problems on the blackboard which Dantzig thought were homework and he copied them down and spent a few days solving them.

What he did not know was that these were not ordinary exercise problems, but two famous, as yet unproven theorems of statistics.

“A few days later”, so reported George Dantzig later in an interview, “I apologized to Neyman for taking so long to do the homework – the problems seemed to be a little harder to do than usual. I asked him if he still wanted the work. He told me to throw it on his desk. I did so reluctantly because his desk was covered with such a heap of papers that I feared my homework would be lost there forever.

About six weeks later, one Sunday morning about eight o'clock, Anne and I were awakened by someone banging on our front door. It was Neyman. He rushed in with papers in hand, all excited:

> *I've just written an introduction to one of your papers. Read it so I can send it out right away for publication.*

For a minute I had no idea what he was talking about. To make a long story short, the problems on the blackboard which I had solved thinking they were homework were in fact two famous unsolved problems in statistics. That was the first inkling I had that there was anything special about them.”

The following year, when Dantzig asked Neyman, the most respected statistician in the world at the time, what topic he could choose for his doctoral thesis, Neyman just shrugged and told him to wrap the two problems in a binder and he would accept them as his thesis.

George Bernard Dantzig was born in Portland, Oregon, the eldest son of Tobias Dantzig and Anja Ourisson. The parents had met while studying at the Sorbonne in Paris, where they attended lectures by Henri Poincaré, among others. After their marriage, they emigrated to the USA, where Tobias Dantzig, originally from Lithuania, had to earn a modest living by doing odd jobs as a lumberjack and road builder because of his language problems, before earning a Ph.D. in mathematics at Indiana University. His wife took a Master's examination in French.

The parents thought that their children would have a better chance in life if they gave them the first names of famous personalities. So the elder son was named George Bernard in the hope that he would one day become a writer (like George Bernard Shaw), and the younger son was given the first name Henri (like Henri Poincaré) – in fact he too later became a mathematician.

Their mother worked at the *Library of Congress* in Washington DC and their father taught mathematics at various universities: *Johns Hopkins* (Baltimore, Maryland), *Columbia University* (New York) and the *University of Maryland*. In 1930, he published a book on the history of the development of mathematics entitled *Number – The Language of Science*, which was reprinted several times (most recently in 2005).

In his early classes, GEORGE still had difficulties with mathematics, but thanks to his father's training programme with daily tasks, especially from geometry, GEORGE eventually achieved top grades.

Despite both parents working, the family did not have enough money to finance studies in mathematics and physics at one of the elite universities, and so GEORGE DANTZIG began his mathematics studies at the *University of Maryland*. After graduating with a bachelor's degree, he transferred to the *University of Michigan*, where he earned a master's degree in 1937.

Tired of abstract mathematics, he then took a job at the *U.S. Bureau of Labor Statistics* and worked on a study of the consumption behaviour of urban dwellers.

During this work, DANTZIG discovered his interest in statistical questions and methods. In 1939, he asked JERZY NEYMAN at the *University of California* in Berkeley if he could join his doctoral studies (with a *teaching assistantship*), which he was able to do. And so one day the situation described at the beginning came about ...

His doctorate had not yet been completed when the USA entered the war. DANTZIG went to the *Pentagon* in Washington and took a job as head of the *Statistical Control Division* at the headquarters of the *U.S. Air Force*. There he began to realise that the military had insufficient information about the actual stock of aircraft and their equipment. He developed a procedure to collect the required data in all details, especially to prepare a detailed order placement – right down to the need for nuts and bolts.

After the war, DANTZIG returned temporarily to Berkeley and finally earned his doctorate. He turned down an offer from the university to continue his work there – not only for financial reasons, but because the opportunities and challenges of working for the *Air Force* appealed to him more.

Inspired by the method of *input-output analysis* of the Russian-American mathematician WASSILY LEONTIEF, who held a professorship at *Harvard University* in Cambridge (Mass.) from 1931 onwards, DANTZIG saw the need to dynamise this rather static model and moreover to refine it to such an extent that hundreds, if not thousands, of activities and positions could be recorded and optimised. At that time, however, this was still an unimaginable computational challenge.

During his work at the *Pentagon*, DANTZIG recognised that many decisions in the planning processes were only made on the basis of experience and did not take objective criteria into account, so that not necessarily optimal results were achieved. Often, the conditions to be fulfilled (restrictions) could be described with the help of linear inequalities, and by setting an objective function, it was defined what the goal of an optimisation should be: for example profit maximisation or resource minimisation.

DANTZIG developed a planning method that is called *linear programming*, where *programming* did not mean programming in today's usual sense, but was the term used in the military for the planning of processes. The term *linear* referred to the chosen modelling by linear functions.

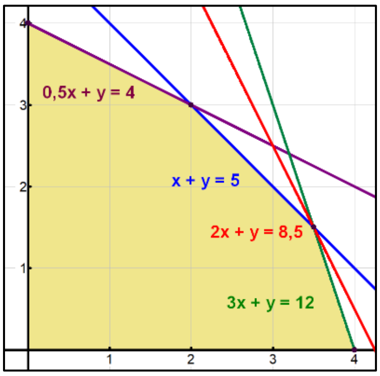
A linear inequality defines a half-plane in 2-dimensions and a half-space in 3-dimensions. If several inequalities are considered, convex polygons or convex polyhedra are created accordingly – in the *n*-dimensional case a corresponding convex structure is called a *simplex*.

Example: Suppose that the restrictions of a real-life situation result in the linear inequalities

$x \geq 0;\ \ y \geq 0;\ \ x + y \leq 5;\ \ 0{,}5x + y \leq 4;\ \ 3x + y \leq 12$.

The yellow-coloured (convex) area is defined by these inequalities. Every point of the convex area fulfils all given inequalities.

If then the objective function in the subject context is given by the equation $z(x, y) = 2x + y$, then this function of two variables takes the largest possible value if $x = 3.5$ and $y = 1.5$ i.e. if $2x + y = 8.5$, cf. the straight line drawn in red.



This solution can be found graphically because the member of the set of lines g_a with $y = g_a(x) = -2x + a$ with the largest possible a just passes through a point of the polygon (possibly coinciding with a boundary line). In general, only vertices of the polygon need to be considered as solutions to this optimisation problem. Therefore, it is sufficient to determine the values of the objective function at the vertices of the polygon.

In the case of three variables, it is often difficult to imagine the position of the planes and their intersections; in the case of a simplex of a higher dimension, the visualisation is completely lost, and the search for the optimal corner point can become a computationally very complex problem.

DANTZIG's solution to the problem is done by introducing so-called *slack variables*, by which a linear system of equations is generated from the system of inequalities: $x + y + u = 5;\ \ 0.5x + y + v = 4;\ \ 3x + y + w = 12$. Here, unused "capacities" are described by the auxiliary variables.

Also in 1947, DANTZIG invented a systematic method for the computational determination of the optimal solution, the so-called *simplex algorithm*, about which he himself said:

> *The tremendous power of the Simplex Method is a constant surprise to me*.

The first improvement to the method came at the end of the year, when DANTZIG went to Princeton to seek the advice of JOHN VON NEUMANN. This brilliant mathematician and computer scientist immediately recognised analogies between the method of linear optimisation and the algorithms presented by him and OSCAR MORGENSTERN in their recently published book *Theory of Games*.

Over the years, the search methods were improved considerably, especially through the use of computers. Other approaches were also pursued, including non-linear modelling, but ultimately the linear programming method developed by DANTZIG proved to be sufficiently effective.

TJALLING KOOPMANS, Professor of Research in Economics at the University of Chicago, recognised the economic significance of linear planning after a conversation with DANTZIG. This then led to his theory of the optimal use of resources.

To the astonishment of all the experts, DANTZIG was left empty-handed when KOOPMANS was awarded the NOBEL Prize for Economics for this in 1975 – together with the Russian mathematician LEONID VITALYEVICH KANTOROVICH, who had already described similar approaches in 1939. However, these only became known in the West two decades later. DANTZIG, who was always friendly and attentive to his fellow men, bore this with great composure and proved his high level of competence by tirelessly continuing his activities.

After his work with the Air Force, DANTZIG moved to the *RAND Corporation* in Santa Monica in 1952 to further develop the computer-based implementation of procedures. In 1960, he accepted a professorship in the *Department for Industrial Engineering* at Berkeley and founded the *Operations Research Center*.

His book *Linear Programming and Extensions* (Princeton University Press), published in 1963, became the standard work on linear optimisation. From 1966 onwards, DANTZIG worked at Stanford; among other things, he founded the *Systems Optimisation Laboratory* (SOL) there.

For more than 30 years, he supervised 41 doctoral students who, with a degree from DANTZIG, had brilliant professional and academic careers ahead of them.

He was frequently honoured for his numerous scientific contributions through memberships in academies and honorary doctorates, including the *National Medal of Science* and the *JOHN VON NEUMANN Theory Prize*. The *Society for Industrial and Applied Mathematics* (SIAM) and the *Mathematical Optimization Society* (MOS) honoured the scientist and his achievements by awarding the GEORGE B DANTZIG Prize every three years.

A few weeks after a festive event on the occasion of his 90th birthday in 2004, his health deteriorated rapidly; a diabetic disease together with cardiovascular problems led to his death.

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