Publication: Mail & Guardian, Careers
Date: Friday, July 07, 2017
Page: 31

Advertorial

Who develops the "recipes" — or rather algorithms — and to what extent can we trust computers with the answers?

Computers do not know all the answers

Professor Ben Herbst

At the most basic level, computers can assist us to investigate and discover surprising new physical phenomena, investigate known phenomena in more detail, or extract patterns from vast amounts of data. But back in the 1950s there were a few nasty surprises when it became clear that the results produced by this new technology could not always be trusted.

In the early years, for example, there was one specific problem that caused a lot of headaches. This was the fact that computers do not use exact arithmetic, but round off numbers because of their finite capacity.

It doesn't really matter how good the round-off is, even if it is very good. In one notorious instance involving the European Space Agency in 1996, an unexpected round-off error caused the destruction of the Ariane rocket 37 seconds after lift-off.

Today we know that things can go wrong in different ways, not only due to round-offs, and researchers spend much of their time identifying these situations and finding ways to avoid them. This has initiated a completely new research field called numerical analysis, which today is fundamental to all scientific calculations performed on a computer.

What is numerical analysis?

Numerical analysis focuses specifically on the study and development of algorithms, which are the "recipes" according to which calculations are performed on a computer.

One of the first physical experiments — today we call them computer simulations — performed solely by a computer, was done in the 1950s by Enrico Fermi, John Pasta, Stanislaw Ulam and Mary Tsingou, better known as the FPUT experiment. The results were completely unexpected, and until today there are still articles being published trying to explain them in more detail. What happened, and why?

Surprisingly the answer for many of the problems identified by early researchers can be found in the complex plane. Take the ordinary, real numbers -1, 0 and 1. Any two of them can be added, multiplied, subtracted or divided and the result will still be one of these numbers.

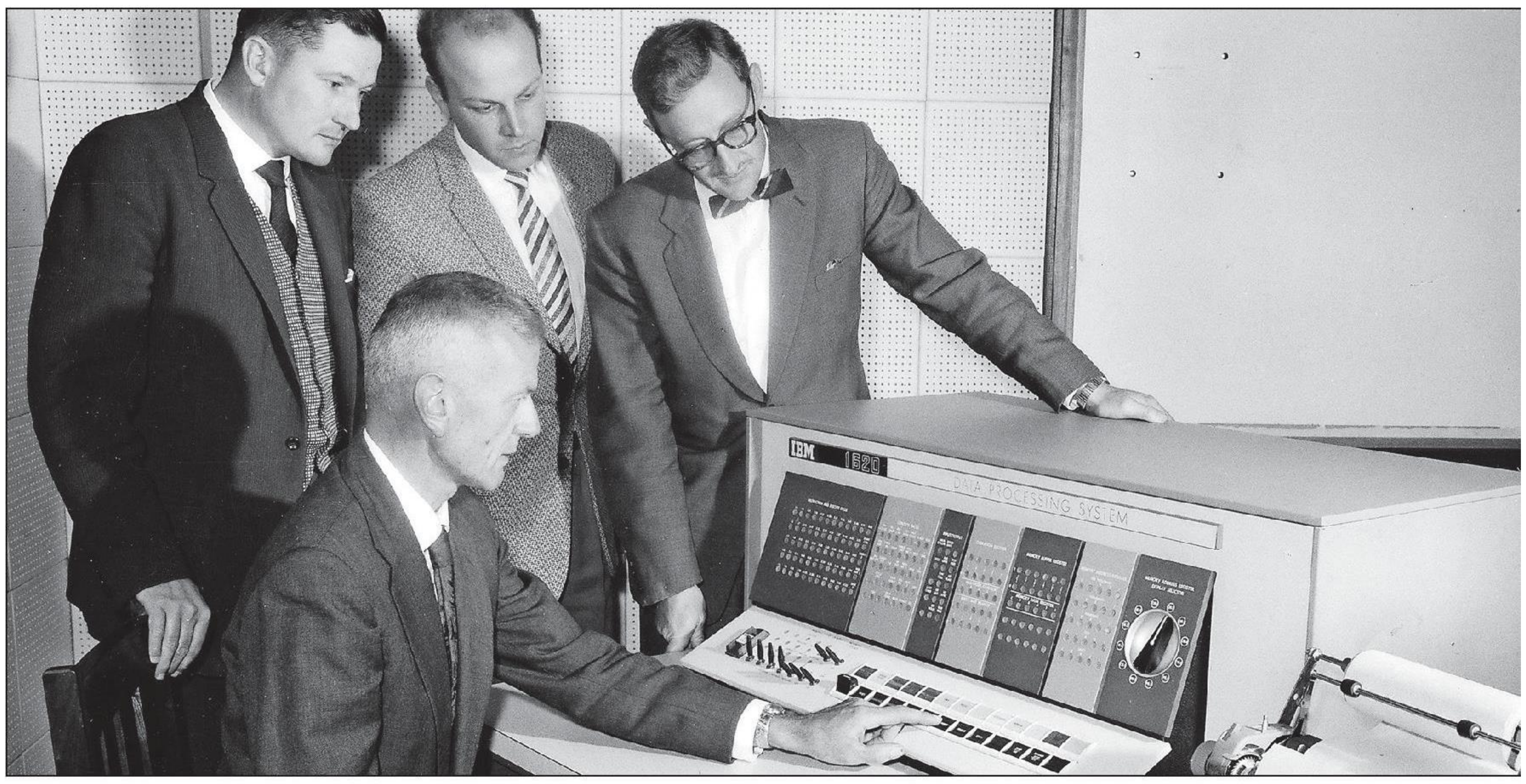
However, if you calculate the square root of a negative number, you leave the real line and end up in the complex plane. At first glance it seems as if the two realms do not have much in common; you can easily devote your entire life to the study of those processes described by the real numbers.

Perhaps because of this fact there is an unfortunate tendency at many mathematical departments to de-emphasise the study of the complex plane.

It is astounding to realise that the behaviour of calculations of functions on the real axis are determined by what is happening in the complex plane. While this fundamental insight dates back to the 19th century, the advent of the modern electronic computer requires that mathematicians face this simple truth head-on. Sometimes advanced mathematics is required to understand some of the most basic of processes, such as the numerical calculation of simple functions.

Said differently, one would be wise not to trust everything that comes out of a computer — things can go wrong in unexpected ways!

Ben Herbst is a Professor of applied mathematics at Stellenbosch University. His research interests include machine learning, image processing and computer vision, as well as instabilities in discretizations of nonlinear partial differential equations. *herbst@sun.ac.za*



In 1963, Stellenbosch University was only the second university after Wits to acquire a computer. Here, a group of SU researchers and managers admire the "fantastic tempo" of the IBM-1620 computer Photo: SU Archive