THE BEAUTY OF MATHS

"Mathematics, rightly viewed, possesses not only truth, but supreme beauty – a beauty cold and austere, like that of sculpture…" BERTRAND RUSSELL

Mathematics is, at its heart, the study of patterns, structure and regularity. As such, it has long been the central tool in understanding, organising and making sense of data. Now, in a world in which we confront the "information glut", it is increasingly important to extract useful information from huge sets of data. To do this, a large area of research is fast developing, called "machine learning" – an area that is proving hugely useful, as well as fascinating in its own right.

In medicine, for example, automated techniques to aid diagnosis and predict prognoses, based on experience, will be of great use to doctors – and their patients. In engineering applications, we want computers to perform cognitive-type tasks such as recognition of handwritten letters or digits, or facial recognition. For security or fraud-detection applications, systematic detection of anomalous behaviour will be increasingly useful. And we want better spam filters that will, on the basis of experience (such as a record of users blocking particular messages), recognise and reject junk email.

At their core, all these problems involve some or all of the following generic tasks:

- Classification of data into two or more types or classes, using as a guide the known classifications of some previous data.
- Clustering of data into "similar" groups.
- Detection of "unusual" data: that is, outliers.

Given the commonalities between these (and other) applications, there is much to be gained from developing general techniques for solving the generic tasks identified. Since many of the datasets from which we want to learn or infer patterns are enormous, ad hoc techniques are just not useful. What is needed are principled, provably effective methods which are also efficient, in the sense that they can work quickly enough to be of practical use.

This is where machine learning comes in. It is a large area of research activity involving mathematicians, statisticians, computer scientists, engineers, and others, working together to develop efficient general procedures (or algorithms), for tasks such as these. Many very general machine learning paradigms have been developed. Some have their roots in classical artificial intelligence, closely related to mathematical logic. Others looked to biology for inspiration: for example, there was a huge surge of interest a couple of decades ago in artificial neural networks. Popular methods include support vector machines, decision trees and (as has long been the case) increasingly sophisticated statistical methods.

In all of these developments, mathematical analysis is essential. Modelling learning or pattern recognition tasks inevitably involves the theory of probability if one is to be able to say anything useful. Analysing the effectiveness and efficiency of the algorithms requires discrete mathematics and computational complexity theory.

To date the most successful approaches have drawn together a variety of techniques and ideas from a range of advanced mathematics, including probability theory, combinatorics, geometry and algebra. Although it is interesting to know that the mathematical work might inform or provide theoretical underpinning for the development of general learning algorithms, which may then be potentially useful in real-world applications, that is not the primary motivation for mathematicians.

What really fires mathematicians is that the problems that arise are very often interesting in their own right. In seeking to solve them, we can appreciate what Bertrand Russell described as the "stern perfection" of mathematics. Like much university research, this work is theoretical, but (as Kurt Lewin and others have said) there is nothing so practical as a good theory. ■

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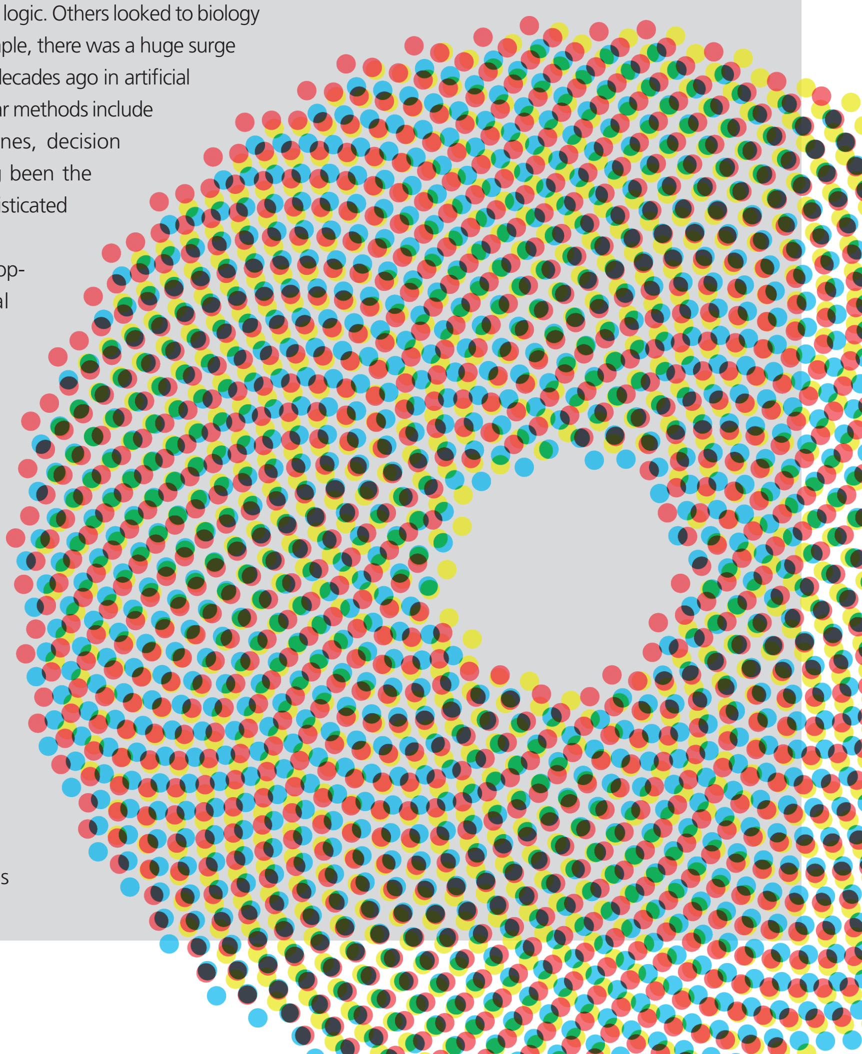

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