Editorial: Go, Forecasts, Faults and Puzzles

The ancient Chinese game of Go has fairly simple rules and is considered to be the oldest board game that has been played continuously until the present. Nevertheless, it often involves very complicated abstract strategies. Mathematicians and computer scientists John Tromp (Netherlands) and Gunnar Farnebäck (Sweden) recently determined that Go has more than 2×10^{170} legal playing positions [1]. For comparison, there are believed to be only about 10^{80} atoms in the universe and about 10^{46} legal playing positions for chess. Perhaps unsurprisingly then, in mid-October the journal *Nature* published an article that explained how a deep neural network algorithm has become the first computer program to defeat a Go world champion without any human training [2]. This lack of supervised learning is a significant breakthrough that leads us closer to achieving artificial intelligence beyond our capabilities, especially for applications with no human knowledge or expertise.

Elsewhere in October, Scotland was temporarily declared snow free as all remaining ice melted from Braeriach in the Cairngorms. Since the late 1800s, this event previously occurred only in 1933, 1959, 1996, 2003 and 2006 [3]. Of particular interest to me is how one might use only these data to forecast when the next complete British ice melt will occur. A good starting point is to note that the corresponding frozen periods of $>33, 26, 37, 7, 3$ and 11 years are generally diminishing, as displayed in Figure 1. The first observation is right censored (a lower bound), so we have only five event observations and could fit a quartic polynomial to them perfectly. However, such over-fitting would result in a model that is not robust and leads to absurd forecasts. Simple linear regression for a log-transformed response would be better, predicting that the next British ice melt will occur in 2020 or 2021, though we should seek other information and better models.

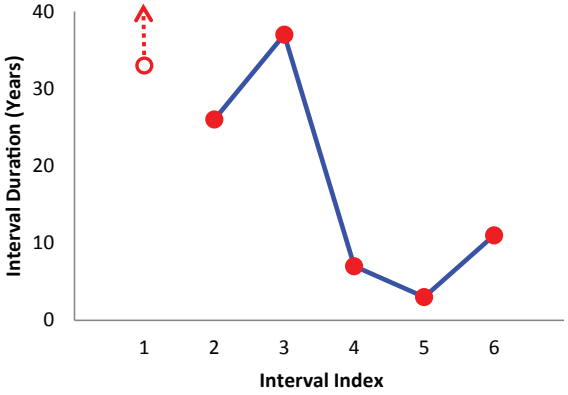

Figure 1: Intervals between recent British ice melts.

The need for such predictions based on sparse temporal event data often arises for reliability engineers who work on safety critical systems. They typically develop deterministic or stochastic models in order to generate accurate and reliable forecasts, such as Markov chains, time series, Poisson processes and dynamical systems. These then enable timely maintenance interventions to delay or avoid future failures, which can take the form of repair, inspection, prevention and replacement. Already scarce event data become rarer still as these analyses help to improve system safety; victims of their own success perhaps. When available, expert knowledge and condition monitoring information help to alleviate this problem. Similar challenges arise for climatologists, meteorologists, seismologists and volcanologists. The timeline in Figure 2 displays all eruptions of Mount Vesuvius since the famous disaster that destroyed Pompeii and Herculaneum, near Naples in Italy. When would you predict the next eruption to occur?

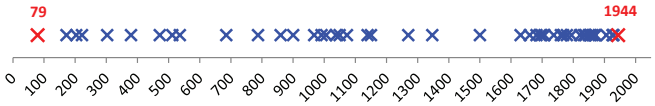

Figure 2: Eruptions of Mount Vesuvius since AD 79.

Also during October, my wife and I employed a local builder to lay some new steps and a path in our back garden; see Figure 3. Notice how the flags' dimensions generated longitudinally aligned borders for the steps, whereas the path was laid in an alternating pattern for aesthetic appeal and to avoid such fault lines. By coincidence, I attended an entertaining IMA branch talk just three weeks earlier, in which Bernard Murphy considered similar problems in connection with teaching mathematical proof and reasoning. In particular, fault-free tiling of rectangles using dominoes was discussed and this led to some surprising results including a close relationship with the Fibonacci numbers. Fault lines are well-known natural phenomena, but are also important considerations for Yale locks, pallet stacking, close packing of objects such as oranges and eggs, brick walls, slate roofs and wooden flooring.

Figure 3: Tiling patterns.

Back in September, radiocarbon dating on the Bakhshali manuscript at the University of Oxford's Bodleian Libraries revealed that the oldest recorded use of the number zero dates from the third or fourth century, hundreds of years earlier than presumed. The former record holder dates from the ninth century and appears on a temple wall at Gwalior Fort in India. Although zeros were previously used in several ancient civilisations, they represented *nothing* rather than a number, so this discovery is quite remarkable. Also during September, though of far less importance, my father proudly showed me his completed spherical jigsaw puzzle as displayed in Figure 4. Ignoring the connecting tabs and blanks, there are 12 regular pentagons, 20 regular hexagons and 180 isosceles trapezia in two subsets of 60 and 120 similar pieces. Maybe you recognise the resulting object as a modified version of the Archimedean solid known as a truncated icosahedron, which is the familiar pattern used to make footballs. Some clever geometry and trigonometry must have been used to design this puzzle.

Figure 4: Spherical puzzle.

I hope that you enjoyed reading October's special issue Maths in Space, which covered the fascinating topics of space missions, interplanetary transfers, non-linear optimisation, uncertainty

quantification and gravitational waves. It reminded me of Ian Stewart's *17 Equations that Changed the World*, which was rightly awarded the Euler Book Prize in January. In a chapter describing Newton's law of gravity, this book discusses simple Hohmann transfers between elliptical orbits, Lagrangian points of stability relative to two large bodies, and the Interplanetary Transport Network of fuel-efficient (though time-consuming) transfer paths through space. The last of these astonishing discoveries arose through the imaginations of American mathematicians Charles Conley and Richard McGehee in 1968, and through the development of powerful numerical algorithms for determining orbits in the presence of three or more large bodies. Astronomy always serves to remind us how utterly insignificant the human race is on a cosmic scale.

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Back on earth, I am delighted to welcome Dr Ellen Brooks Pollock to the *Mathematics Today* Editorial Board. She is a Fellow of the IMA and a Lecturer at the University of Bristol, where she actively conducts mathematical modelling research in the fields of public health and epidemiology. These skills complement those of other Board members so her contributions will be greatly appreciated. Ellen has published several papers on infectious diseases and you might recall that she won the Catherine Richards Prize (https://ima.org.uk/awards-medals/catherine-richards-prize/) in 2011 for her article *Pigs didn't Fly, but Swine Flu* with co-author Ken Eames, a version of which also featured in the IMA's golden anniversary book *50 Visions of Mathematics* in 2014.

The IMA conference programme continues to flourish, with more successful new events to report, including a second 16+ School Student Event organised this summer at Loughborough University by our Vice President for Communications, Noel-Ann Bradshaw. We also held our first Conference on Mathematics of Operational Research at Aston University in conjunction with the Operational Research Society. IMA Mathematics 2017 was well appreciated as in previous years, while the biannual Early Career Mathematicians conferences remain popular and EDF Energy has just hosted a sixth IMA Employers' Forum. Please glance through the list of forthcoming conferences and branch activities, as they have widespread appeal and your attendance would certainly be welcome.

Along with our regular networking items, December's issue contains Chris Linton's Presidential Address *Cultural Challenges Facing the Mathematical Sciences* and a fascinating feature *Exploring Steiner Chains with Möbius Transformations*, which won this year's Catherine Richards Prize for Early Career Mathematicians. We also have a fabulous selection of articles on Georg Cantor, wind turbines, maths and painting, Bernard Bolzano, Historical Notes (Fibonacci and zero) and Westward Ho!

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References

1 Tromp, J. and Farnebäck, G. (2016) *Combinatorics of Go*, http://tromp.github.io/go/gostate.pdf (accessed 27 October 2017).

2 Silver, D., Schrittwieser, J., Simonyan, K., et al. (2017) Mastering the game of Go without human knowledge, *Nature*, vol. 550, pp. 354–359.

3 Watson, A., Duncan, D. and Pottie, J. (2007) No Scottish snow survives until winter 2006/07, *Weather*, vol. 62, pp. 71–73.