RTT TECHNOLOGY TOPIC
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NETWORKS THAT KNOW-THE FUTURE

In last month's Technology Topic, The Armstrongs, we used the example of FM modulation to highlight how technology innovation can be frustrated by legacy adoption barriers and vested commercial interests. In comparison we referenced Qualcomm as a text book example of how to parlay clever maths into a $100 billion dollar business.

The coding schemes used by Qualcomm's original company, Linkabit, can be directly linked back to the work of Jacques Hadamard on matrix maths in the 19th century.

Similarly the inferential algorithms used by Amazon and the Alphabet Group and Apple can be traced back to three 18th and 19th century mathematicians, the Reverend Thomas Bayes, George Boole and Augustus De Morgan and on a longer time scale to the scientific traditions of Ancient Greece, in particular the work of Aristotle and the ninth century Persian scientist Abdullah Muhammad bin Musa al-Khwarizmi and his work on algorithms.

In this month's technology topic we set out to examine how and why what are at heart fairly straight forward mathematical concepts with a provenance between three hundred and two thousand years old have propelled Apple, Amazon and Alphabet to a combined enterprise value of three trillion dollars (with Facebook and Netflix close behind).

To put this into context this is more than the annual GDP of the UK ($2.6 trillion), India ($2.6 trillion), France, ($2.5 trillion), Brazil ($2 trillion), Italy ($1.9 trillion), Canada ($1.6 trillion) and more or less twice the GDP of South Korea ($1.5 trillion), Canada ($1.6 trillion), South Korea ($1.5 trillion), Russia($1.5 trillion) and Australia ($1.3 trillion). As my colleague John Tysoe from The Mobile World likes to point out, **A**pple, **A**mazon and **A**lphabet together with **F**acebook and possibly **N**etflix, five US companies all less than 25 years old, could buy the whole global telecommunications industry and still remain under geared.

Though this is unlikely due to regulatory constraints and competition policy there are already investment touch points between these web scale players and terrestrial mobile and satellite operators. Crucially these companies not only have cash but customers and unprecedented visibility to what those customers want and need and are doing at any moment and place in time.

Apple, Amazon and Alphabet, their Asian counterparts, Baidu, Ali Baba and Ten Cent and the social media platforms that exist alongside are building networks that know what we want and need before we do. We are already living in an age where social networks are credited with winning or losing elections but this is not the same as knowing the future. By combining massive computing power with ever more powerful associative maths next generation networks will be able to foretell not only our individual futures but the future of the world in which we live.

But as always if we want to know the future the best starting point is the past.

How 18th Century English Clergy shaped today's internet world

The Reverend Thomas Bayes (1702-1761) was a major contributor to the science of conditional probability in which 'a hypothesis is confirmed by any data that its truth renders probable.' His 1764 paper, *An Essay toward Solving a Problem in the Doctrine of Chances*' provided the foundation for modern gambling algorithms.

George Boole (1815-1864) developed Bayes work by introducing more precise conditional language, the eponymous Boolean operations of OR (any one of the terms are present, more than one term may be present), AND (all terms are present), NOT (the first term but not the second term is present) and XOR (exclusive OR, one or other term is present but not both).

Augustus De Morgan (1806-1871) was working in parallel to Boole on limits and boundaries and the convergence of mathematical series. The work of Augustus De Morgan is directly applied to the truncation of iterative algorithms so that an optimum trade off can be achieved between accuracy and time. This is known as De Morgan's Law.

Every time we use a search engine we are using a combination of De Morgan's Law, Boolean operations and Bayesian conditional probabilities and it is the these three cornerstones of probability theory that together allow Amazon, Apple and Alphabet and Facebook to build networks that know what we want and need before we do.

The two key enablers that have made the maths make money are GPS and modern smart phones which together allow us to interact and navigate and have knowledge of the physical and commercial world around us. The network knows where we are and what we might want to do there. This in turn has depended on a parallel development of mobile metadata algorithms.

Metadata is information about information, data that is used to describe data. It comes from the Greek meaning 'among', 'with', 'beside' or 'after'.

Aristotle's work 'Metaphysics' written sometime around 310 BC theorized about the common structures that underlie the changes that are observable in the natural world. In a modern mobile context, metadata may be spatial (where), temporal (when) and social (who). It can be manually created or automatically created. Information about information can be more valuable than the information itself. Semantic data is metadata that not only describes the information but explains its significance or meaning. This implies an ability to interpret and infer (Aristotle). Modern mobile inference algorithms include similarity processing algorithms and sharing algorithms. Put simply, metadata is a mechanism for increasing user engagement and creating and extracting user value.

But life moves on and it is important to realise that mathematical and algorithmic techniques continue to evolve. Some of the mathematical value both in pure and applied maths is 'heritage value', the legacy of several thousand years of mathematical study and inspiration. Some of the mathematical value is 'contemporary value', the contributions presently being made by practicing mathematicians and significant additional value will be realised from future generations of mathematicians.

So if we want to know what Amazon, Alphabet, Apple and Facebook and their web scale companions might do next it is useful to consider the areas in contemporary mathematics that are most likely to prove useful in terms of differentiating the future 'user experience proposition' or create new sources of revenue.

One way to do this is to find out what work, or more accurately, whose work is winning awards.

For years there was no mathematical equivalent to the Nobel Prize. Rumour has it that the Swedish mathematician Gosta Mittag Leffler had an affair with Alfred Nobel's wife. This effectively shut out all future mathematicians, particularly Swedish mathematicians, from the Nobel award and recognition process.

There is a Field award for mathematicians but this is only awarded every four years and is restricted to mathematicians under 40. In 2002, the Norwegian government decided to fund a yearly award known as the Abel prize to mark the double centenary of Niels Henrik Abel. Niels Henrik Abel died in 1829 at the age of 27 after contracting TB following an ill-advised sleigh ride. In

his short life he had however developed the foundations for group theory, also worked on in parallel by Galois.

Group theory is essentially an integration of geometry, number theory and algebra. Abel worked specifically on the commutative properties of group operations, arithmetical processes like addition where it does not matter in which order sums are performed and where operations have a reciprocal influence on each other. Group theory helps discover and describe what happens when one does something to something and then compares the results with the result of doing the same thing to something else, or something else to the same thing. Group theory is therefore crucial to the management and manipulation of complex and interrelated data sets that change over time at varying rates.

Group theory and the associative maths behind group theory is changing how value is generated in the telecommunications industry. This is why it is useful to track who is winning the Abel prize each year, a prize worth $1 million dollars to the winner but potentially trillions of dollars to companies that find ways of using the maths to generate new profit opportunities.The table below summarises the winners by year and research topic.

Year	Awarded to	For work on
2003	Jean-Pierre Serre	Topology (place and space) and group theory
2004	Sir Michael Francis Atiyah and Isadore M Singer	The Atiyah-Singer index theorem, a construct for measuring and modelling how quantities and forces vary over time and space taking into account their rate of change.
2005	Peter Lax	Nonlinear differential equations and singularities, the modelling of odd things that happen at odd times.
2006	Lennart Carleson	Harmonic analysis and his theory of smooth dynamical systems.
2007	Srinivasa SR Varadhan	The maths describing rare chance and probability events and a unified theory of large deviation.
2008	John Griggs Thompson Jacques Tits	Algebra and group theory
2009	Mikhail Gromov	Geometry
2010	John Tate	Number theory.
2011	John Stony	Topology, geometry and algebra.
2012	Endre Szemedi	Discrete mathematics and theoretical computer science, additive number and ergodic theory (the statistical and qualitative behaviour of measurable group and semigroup actions).
2013	Pierre Deligne	Algebraic theory and representation theory
2014	Yakov Sinai	Dynamical systems, ergodic theory and mathematical physics
2015	John F Nash and Louis Nirenberg	Nonlinear differential equations and geometric analysis
2016	Sir Andrew Wiles	For proving Fermat's Last Theorem by way of the modularity conjecture for semi stable elliptic curves opening a new era of number theory. Pierre de Fermat (1607-1665) created the Last Theorem while studying Arithmetica, the Greek text written in AD 250 by Diophantus of Alexandria discussing whole numbers, the relationships between them, and the patterns they form and the relationship with Pythagoras' 'square of the hypotenuse theorem' Unfortunately Pierre De Fermat didn't note down how he had done it.
2017	Yves Mayer	Mathematical theory of wavelets
2018	Robert P Langlands	Connecting representation theory to number theory

Surprisingly there are no Chinese mathematicians though presumably this will change over time.

So what can be inferred from this list of prize winners and their work?

Apple, Amazon, Alphabet and Facebook all presently earn their money by identifying individual wants and needs and meeting those wants and needs though the supply of physical goods (Amazon) or advertising. Adding mobility, place and time and direction and speed of travel increases the value of these services.

More fundamentally, these services generate data sets that can be analysed to reveal social, economic and political trends. If Apple, Amazon and Alphabet combined their data sets, none of us would have any secrets.

Our 16 prize winners are all directly or indirectly engaged with furthering the science and methodology of associative maths. When combined with massive computing power, associative maths reveals what's going to happen next, a clairvoyant computing system.

A clairvoyant computing system has minimal value until it is closely coupled with a communications system at which point it can potentially rule the world. This may provide a compelling rationale for the web scale majors to invest more aggressively into mobile and satellite operators and their associated supply chains.

This may of course be frustrated by regulatory and competition policy but it does point to a fundamental shift from value generated from individuals and the relatively small groups that those individuals interact with to a far reaching business model with profound implications for sovereign governments and their governing institutions.

The interesting twist is that Apple, Amazon, Alphabet, Facebook and Netflix are US companies but global corporations with global reach but minimal sovereign sympathy. Ali Baba and Ten Cent and Baidu have a similar numeric demographic though may find it harder to scale into non-Asian markets. This could change but they will still lack the first mover advantage of the established US majors.

But the financial scale is potentially extraordinary.

Just to reiterate, Apple, Amazon and Alphabet are all now individually valued at more than one trillion dollars with Facebook and Netflix close behind them. Their combined knowledge of how we work rest and play is unprecedented. If the behaviour of people and groups of people can be predicted then people can be managed and controlled however that also implies that the events that these people are part of can be predicted and managed as well.

The French Physician Michel de Nostradamus (1503-1566) published his Prophecies in 1555 after spending many hours staring at a bowl filled with water and herbs. He accurately foretold the date and manner of death (a jousting accident) of Henry the Second and is credited with predicting the French Revolution, the rise of Napoleon and Hitler, the development of the Atomic bomb and the attack on the World Trade Centre on September 11 2001. Like all clairvoyants he managed to combine vagueness of detail and date with the occasional lucky break, not so lucky for Henry Second though he must have known that jousting was a dangerous sport.

The next generation of *networks that know* are going to be more detailed and accurate (most of the time).

Let us hope that their power can be harnessed as a force for social, economic and political progress.

Ends

If you are interested in further background on this topic, our book Making Telecoms Work dedicated a whole chapter to Information Centric Software. Published in 2012 it remains more relevant than we might have expected and is **available in E book and hard back.**

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