TOMORROW'S HEADLINES, MODELLED TODAY

Mathematics, physics, computer science, game theory — Jasmine revolution, Anna protest, terror strikes, food riots. Elegant scientific theories and techniques are being increasingly used to predict and analyse large and messy social conflicts. The 'new social science' can be surprisingly accurate and useful. India is taking baby steps in a field that can revolutionise public policy

RAJ

THE MATHEMATICS OF ANGER & HOPE

:: Hari Pulakkat

Media reports are superficial sources of information for scholarly pursuits, but only when seen through human eyes. Kalev Leetaru, a text analytics specialist at the University of Illinois, put a set of media reports under the penetrating gaze of Nautilus, a supercomputer based at the University of Tennessee. The computer analysed 30 years of data from around the world, containing 100 million news reports, 10 billion names and activities and 100 trillion relationships.

Leetaru was looking for a method to forecast large-scale human behaviour, and he thought he found it at the end of his analysis. He had looked deeply at the tone and frequency of words used in news reports. He was particularly interested in spikes of negative sentiment, which he closely associated with an imminent revolution. He found such sentiments in the days leading up to the recent revolutions in Tunisia, Egypt and Libya. They were no coincidence, according to him. Several other major events – the 1990s ethnic conflict in the Balkans, for example – were also associated with spikes in negative sentiment.

Half a Million DVDs

"People do not wake up on a Friday morning and decide to start a riot," says Leetaru, who is assistant director for text and digital media analytics at the Institute for Computing in the Humanities, Arts, and Social Science at the University of Illinois. "There is a long slide towards such events." The fate of Hosni Mubarak is one of Leetaru's prime exhibits. "Everyone said he would last the revolution because he had lasted 30 years. But analysis showed that this revolution was different."

Leetaru had measured the density of emotional language. Algorithms helped him score words for their emotional weight and then classify them as positive or negative. He also analysed the results in statistical terms and threw up results that looked like a stock price graph. Leetaru could then easily spot the spikes in collective national emotion, which are usually evident before an extreme event takes place.

Leetaru now applies his textual mining skills to understand global social problems. Social science did not have such specialists till recently because the world had no data to analyse. The advent of digitised text and then the social media and Twitter has put in front of computer scientists an enormous amount of information to analyse. And advances in computing technology have given them the ability to analyse this information quickly.

Thirty years worth of media coverage consisted of 2.4 petabytes of data, roughly equal to half a million DVDs or 20 billion

WHAT IS COMPUTATIONAL SOCIAL SCIENCE?

- There's vast data about people & behaviour patterns
- Modern computers can analyse vast amounts of data
- Scientists have the tools to study complex systems
- Some scientists are applying these tools to study complex social behaviour
- Computational methods are providing surprising insights about social outcomes

HOW CAN YOU FORECAST TERRORIST STRIKES?

- Terrorist strikes have happened over many decades
- This history creates a rich database
- Data analysis shows that they follow maths laws
- Using these laws, one can calculate the probability of a terrorist strike of specific magnitudes
- These forecasts, when fully developed, can be useful for preparing responses

ARE FOOD RIOTS RELATED TO US HOUSING BUBBLE?

- As the bubble bursts, money moves to the stock market
- As the stock market booms and then crashes, money moves to commodities
- Commodity speculation increases global food prices
- High food prices add to the vulnerability of populations that are already stressed
- Such vulnerable populations start rioting

pictures, but modern computers can cut through this mountain easily. And such data analysis is now throwing up surprising facts about human behaviour. "Collective human behaviour is more predictable than we thought," says Aaron Clauset, assistant professor of computer science at the University of Colorado in Boulder.

Probability of Another 9/11

Clauset is a computational scientist. Computation is a step ahead of data mining, in that it simulates events and gives predictions and forecasts. Clauset has been analysing a problem that is now on top of everyone's minds: global terrorism. Specifically, he has been using contemporary statistical methods to investigate the probability of big terrorist attacks.

A terrorist attack is as random an event as you can get, and yet Clauset has found patterns over the years that can be used to forecast big ones. "Forecasting is different from prediction," says Clauset. "You can forecast an earthquake but not predict it." Geophysicists forecast earthquakes in terms of probabilities within a specific time window. They can never say that an earthquake will strike a specific place at a specific time, but the forecast can give enough data to prepare a response when it finally strikes. Similarly, Clauset thinks that global terrorism forecasts can help governments to prepare responses for big terrorist attacks.

In the year 2009, Mitre Corporation in the US finished a study on rare events commissioned by the US Department of Defence. Mitre undertakes public-interest sponsored research. It found that an event like 9/11 has a 7% probability of occurring in the next 10 years. It had used a mathematical relationship developed by Clauset to calculate these probabilities, but the report had also warned that we did not have the ability to predict such events to any accuracy. It had said that methods of physics and engineering provide some guidelines but are of limited value in prediction.

The Next Earthquake

Clauset has been studying the mathematics of terrorism for eight years. His broader interest is to develop statistical methods and algorithms to study complex systems of all kinds. He looks at patterns in random events and develops tools to analyse physical, biological and social systems. Such tools help academicians to analyse the vast data that we now accumulate across the world on social behaviour.

Clauset differs with the Mitre estimate. According to him, the probability of an event like 9/11 occurring is 3% every year in the future, and 30% over the next 10 years. Compare this with the probability of a great earthquake (magnitude 8 or more) occurring in the middle Himalayas in the next 25 years. It is about 17%, but geophysicists consider it serious enough for us to prepare a response right now.

Scientists like Clauset are increasing in number across the world, as physicists and engineers use their tools to study collective human behaviour. The study of complex systems is now a hot academic pursuit in developed countries. Several universities there have recently started institutes and academic programmes in the study of complex systems, but India still lags behind in the field. Computational modelling of social systems has started producing interesting results for policymakers in the West.

Predicting Bomb Sites

Governments in Europe and the US are especially interested in using computation in war and to find terrorists. The US army had zeroed in on Saddam Hussein's hideout after hints from computer simulation of his friendship network and geographies. Conventional analysis had not given any breakthroughs, but computer modelling – using such intangible variables as trust – provided clues that ultimately led the military to him.

Kathleen Carley, a professor of computer science at Carnegie Mellon University, has developed a program that can extract names from news reports and identify people having large connections with other people. These people are influential within a group. Carley uses similar methods to investigate how a terrorist ideology spreads in local populations. Her aim is to develop a method that can stop radicalisation of specific ethnic groups.

Likewise, VS Subrahmanian, director of the Laboratory for Computational Cultural Dynamics at the University of Maryland claims to have developed a program that can identify the location of arms in Iraq to an accuracy of less than a kilometre. The US Defence Advanced Research Projects Agency is developing computational methods that can predict wars, and one such program developed by the University of Washington has been giving predictions every month for more than a year.

Traditional social scientists do not always like such methods. But some of the methods of science and engineering had their origin in social science. "Boltzmann derived inspiration from social science for some of his work," says Clauset, "but they were used more in the physical sciences."

The Austrian physicist Ludwig Boltzmann developed the foundations of statistical mechanics in the second half of the 19th century. It is now proving to be a good tool to attack problems in social science. Statistical mechanics – or statistical physics – is primarily a mathematical framework to study the behaviour of huge collections of particles. Physics needs this framework because conventional physics tools are hopelessly inadequate for studying large collections.

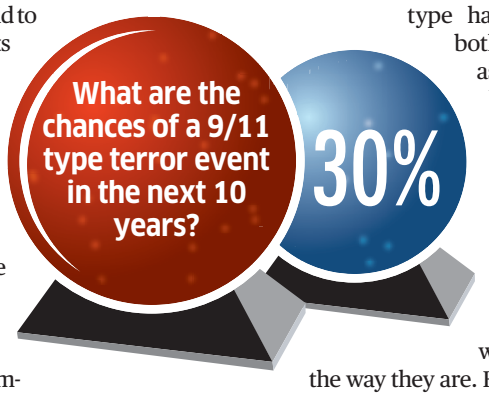
Chaos Theory, Social Practice

Statistical mechanics uses the theory of probability so extensively that is often difficult to distinguish between the two. Physicists also developed some additional tools in the 1970s that are extremely useful to study natural phenomena. In essence, they can be described under three heads: chaos theory or non-linear dynamics, the theory of fractals, and the theory of phase transitions. It took some time for physicists to apply this knowledge to social systems, but they are yielding surprising results when applied.

Chaos theory can be described in several ways; a good way is to call it the study of order in random phenomena. It is a mathematical framework that looks at how complex and unpredictable behaviour can happen with small changes in the initial conditions. Common sense tells us that social systems are ideal for applying this theory, and it turns out to be true at least in part.

Fractals, originally discovered in the 1960s by the IBM researcher Benoit Mandlebrot, are endless repetitions of a structure at different scales. The science of fractals bloomed at the end of the last century. Fractals are ubiquitous in nature, including snowflakes, mountains, rivers, leaves, clouds and others. Some chaotic systems show fractal patterns. Fractals show up in social interactions as well.

The third breakthrough that came in the 1970s is not as easy to describe as the other two. A phase transition is when a system changes phase, like from a solid to liquid or liquid to gas. Physics treats phase transition as an extreme event, and extreme events are ubiquitous in society. "Everything that we care about in society is an extreme event," says Yaneer Bar-Yam, physicist and president of the New England Complex Systems Institute (NECSI) near Boston.



So the mathematics of phase transitions can be used to investigate social conflicts - but with care. "Physics is not the whole story," says Lars-Erik Cederman, professor at the Centre for Comparative and International Studies at the Swiss Federal Institute of Technology in Zurich.

However, physics and computation do provide insights that are difficult to get with conventional methods. Bar-Yam had co-authored a research paper two months ago that linked rise in food prices to conflicts. This is known to be historically true but the computational models tell us more. Bar-Yam and others show that increasing global prices will reach a threshold of instability in July 2012 at current prices, and April 2013, if corrected for inflation.

In a separate paper (published this week), they also show that price peaks are linked to commodity speculation, which in turn is linked to a series of events that can be traced to the housing bubble burst. Just four days before the event that triggered the Tunisian revolution, Bar-Yam and his colleagues submitted a paper to the US government that warned about the consequences of cascading effects across the globe. "So we show it is also possible to identify signatures of unrest and early warning signs," he says.

Computational models tend to be more holistic than conventional social science models. "Non-computational models assume that societies are stable, when they are not," says Cederman. He uses two approaches in his research, one based on computation and the other on geographical information systems (a multidisciplinary field that merges cartography, statistical analysis and database technologies).

His interests include nationalism and integration and disintegration, and his recent research investigates ethnic conflict. Economic theories of civil wars conclude that greed-driven motives are behind reasons for ethnic rebellion. Cederman's research identifies other reasons like lack of access to power and economic inequality.

Modelling Nation-State

In his recent computational work, he investigates the dynamics of state formation. He has shown recently how states attain certain sizes through interplay between pursuit of territorial expansion and physical constraints of maintaining power over long distances. "State formation processes of this type have been operating both in China and India as well, but it would be more difficult to tease out the data in these cases," says Cederman.

He is now beginning a project that will computationally re-run European history to discover why states are shaped the way they are. His aim is to discover what processes drive history, a piece of research that he thinks will be relevant to India and China as well. In the process, Cederman hopes to develop a new generation of computational models for social sciences.

Elsewhere, in other universities, many of his colleagues are developing similar tools with different aims. Within a decade, computational scientists could start giving us insights that can drive policies and shape our world. The next revolution, the next social conflagration, the next terrorist strike: if governments can have a reasonably accurate idea of how and when these events happen, we will live in a very different world. Perhaps, even a better one. ■

PLAY GAMES, MAKE POLICY

:: Mishita Mehra

A lot of people watched the Anna Hazare drama unfold; many with optimism, some with scepticism, yet others with trepidation. Bruce Beuno de Mesquita was probably the only one who took it all in with disappointment. "I followed the case and thought, too bad I don't have the data to analyse this. It would have been a perfect opportunity to apply my model," says Mesquita.

The model in question is a computer algorithm that uses game theory – the mathematical tool used by strategists everywhere from the war room to the boardroom – to focus on problems featuring the dynamics of negotiations, in the face of an opportunity, or a threat or coercion. And the man behind it, Mesquita, is the chairman of the political science department at NYU, and a senior fellow at the Hoover institute at Stanford University. As a consultant to the CIA, the Pentagon, foreign governments, and big corporations, over the past 30 years, he has been known to have made countless accurate predictions on political events in more than 25 countries . For example, he predicted Iran won't finish its nuclear weapons programme, going against conventional American opinion. And he predicted the time Pervez Musharaff would quit his dictator's job in Pakistan.

WHERE THEORY WORKED

US PORTS AND AIRPORTS
Security checks became smarter

3G SPECTRUM AUCTION IN INDIA
Allocation was dispute-free

SOME SCHOOLS, HOSPITALS IN US
Supply of doctors was matched to demand. Same for students & schools

CRIME FIGHTING
NYPD reduced muggings

India Inspired

The good news is that India, although a late entrant, has started taking theoretical techniques like game theory seriously while framing policies or analysing practical problems. For instance, a very sophisticated program was used to design the 3G auctions, using consultants from Britain.

Says the chief economic adviser, Kaushik Basu: "India is beginning to enter this arena... There is enough evidence now that common sense is important but not good enough for economic policy; you do need scientific evidence and deductive reasoning."

National security is a rich subject for game theory. The aim is to deploy limited available resources (security personnel) in a manner that minimises the probability of an adverse event like a terrorist attack. This basic idea has spurred economists to don their thinking hats.

Milind Tambe, a professor at the University of Southern California, for instance, has written papers on how randomised checkpoints can be set up in Mumbai (or any other city). "Humans tend to fall into predictable patterns and checking in a randomised fashion can be applied to any situation, say, like drug trafficking and this has great potential for controlling corruption and crime," he says. Tambe has also addressed several police officers and Central Industrial Security Force personnel at a seminar at the Mumbai airport in June 2010.

What makes him an authority on the subject? Tambe developed a model using game theory that is currently deployed at various airports and ports in the US . According to him, policymakers want a security strategy that is unpredictable, yet covers important targets more frequently, and simultaneously takes into account how the adversary will react. "Game theory provides a mathematical solution to this problem. It's like mathematically solving a problem where they give me the basic parameters, and I just use my computer science expertise to give them an answer based on their own inputs," he adds.

Push from the West

Given that game theory has been around a lot longer in the West – after all John Nash, so ably played by Russell Crowe in the Hollywood hit, *A Beautiful Mind*, was talking about it back in the 1950s – most of the eyebrow-raising work is taking place there. Consider Alvin Roth, professor of economics and business administration, Harvard. Roth has helped design a number of market systems that are deployed in diverse fields, from clearing houses for labour markets (say, for doctors) to kidney exchange, and assigning children to schools in New York and Boston.

Game theory is also being used by several defence agencies across the world. For instance, the Dutch Defence Academy uses game theoretic models to analyse how terrorists organise themselves in a cell within a large network. According to Roy Lindelauf, researcher at the academy, the research is about "how terrorists cooperate and allocate resources, and how this determines the importance of several of those players in a bigger network".

Some economists, like VS Subrahmanian (mentioned in the earlier story) are using game theory to analyse how to reduce terrorist activities. He is in the process of analysing the Indian Mujahideen and other terror groups in the country. "The process is basically like first studying textbooks and other course material and then testing how much you know. In six months we will analyse India; it will take that much time to assemble data," he says.

It's not just the covert side of affairs that has come under the game theory scanner. Indian military think tanks, be it the Institute for Defence Studies and Analyses or the Defence Research & Development Organisation, have recently set up small teams that are trying to apply game theoretic principles to international relations with neighbours like Pakistan.

India's problem is lack of enough data. This can change with projects like the National Intelligence Grid (Natgrid), which got Cabinet approval in July. Under Natgrid, 21 sets of database will be networked to achieve speedy and safe access to information for intelligence agencies. According to GK Pillai, the former home secretary, "In around 18 months when phase 1 for the project is complete, techniques like game theory will be used and this will come under the National Counter Terrorism Centre."

The Spanner in the Works

In the late 80s and early 90s, the New York Police Department carried out a strange experiment, all monitored using secret cameras. They cleaned up and beautified spots where a lot of mugging took place, and discovered something new in the psychology of muggers: people are less prone to criminal behaviour in clean atmospheres. The crime rate went down dramatically when the police beautified the city's toughest areas. That's behavioural economics for you. "NYPD used it successfully. If Indian government offices were nicer, petty corruption may go down," says Basu.

But why would a thief care about ambience? Because rational behaviour is not a given. This violates a crucial assumption of game theory. And "irrationality" has spurred a lot of research.

Researchers have also started realising the crucial role social networking sites like Facebook can play in mapping behaviour more accurately. A recently started "social-network games" project by Microsoft Research, Cambridge, is a good example. The project aims to improve systems by understanding why, and when, individuals, big corporations, and governments behave irrationally.

Pushmeet Kohli, a researcher with the project, says the global presence and popularity of Facebook allows them to study how people from all over the world, not just the West, behave in practice. "We hope this information could be useful for governments and economists," he adds.

Researchers at the psychometrics department of University of Cambridge have also developed a Facebook app called "myPersonality" which has already been used by over 6.5 million people.

"The data connects personality types with 'Facebook Likes'. We have investigated how this data can be used to infer which personality types prefer what: people, places, websites. We can estimate a group's average personality," says Kohli.

The Way Forward

"I think game theory is very useful...[but] using game theory for policy purposes involves lots of careful modelling and attention to detail," cautions Harvard's Roth.

All models are simplifications of reality; they can go wrong on occasions if their assumptions fit poorly with real-world conditions or if the data quality is low. But then, as Mesquita says, this problem is true for any approach. "Game theory makes strong but open, transparent and explicit assumptions while many other means of making forecasts are purely judgemental and not transparent," he adds.

India may have been slow off the blocks but is trying to catch up. Many organisations have begun research in the field. For instance Tata Consultancy Services' innovation lab in Delhi is doing game theory-related research. The company declined to comment on the details of the research.

This reticence is fairly common among India's few practitioners of game theory's public-policy applications and it is largely informed by the nascent stage of research. But there could be plenty to talk about soon. ■

THE THEORY BEHIND THE GAME

Watch *A Beautiful Mind*, *The Dark Knight* and *Rebel Without a Cause*. The first tells you how John Nash, the über game theorist, did his thinking. In the second film, the Joker (Heath Ledger) plays the prisoner's dilemma game in the ferry sequence. And in the third film, James Dean literally enacts the chicken game in the "Chickie Run" sequence. These are two classic games in the theory. Here's a synopsis of the games:

PRISONER'S DILEMMA

Two murder suspects are told if they both confess, they'll get favourable treatment. If neither confesses, they'll spend a short term in jail – as long as it takes for court to hear the case. The evidence is not strong. However, if one confesses and the other doesn't, the squealer walks, while the other gets the maximum penalty. The best outcome for them is that both keep mum. But if they don't trust each other, both will confess. And both will be worse off. That's what game theory predicts. The insight: individuals can try to be better off and end up being worse off. In policy terms, this means good guys must learn to trust each other.

CHICKEN GAME

Two cars are going to collide unless one driver chickens out and swerves. The best outcome for each driver is that the other one chickens out. A crash is the worst outcome for both. Game theory predicts either both drivers will refuse to chicken out or both will play chicken. Neither driver trusts the other to chicken out. So, neither can assume the crash won't happen. The insight here is that in a real confrontation, players can up the ante even if one of them backing down can mean he and everyone will be better off. In public policy, this leads to rules that can anticipate if or when bad guys will back down.