Calculus of crime

George Tita

S Ananthanarayan reports on how the police could use mathematics to outsmart agents of crime

GEORGE Tita, criminologist and assistant professor at the University of California at Irvine, and colleagues have broken down criminal behaviour into elements that allow mathematical methods to predict how patterns would change with different kinds of intervention.

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There are patterns of criminal activity, with some neighbourhoods being the "hotspots", most plagued by burglaries, muggings, car break-ins. Law enforcement agencies try to deploy resources to control crime in these areas in the most effective way, and also keep it from arising in others areas.

These resources are typically limited, whether in the form of funding, trained manpower and technology or even in motivation, as the criminal is usually one step ahead of the police. A manager's approach to fight crime would need to be collecting data, predicting crime patterns and then deploying resources optimally based on data and predictions. George Tita, anthropologist Jeffrey Brantingham and mathematicians Andrea Bertozzi and Martin Short at the University of California in Los Angeles, have modelled crime as a physical system so that mathematics can predict its course in space and time!

Physical systems

Physical systems are routinely studied with mathematics. If an object is moving at a steady speed of "v" kmph, for instance, for a time of "t" hours, the distance "s" which it would cover in this time is given by the formula: "s = v x t". Another example would be the pressure under water. If we know that the pressure increases by a uniform "d" gm/sq cm for every metre we go down, the pressure, "P", at a depth of "l" metres would be given by: "P = d x l".

These are simple formulas for simple, proportionate changes. But if the speed "v" were not steady but was increasing, say by a factor of "a" every second, then the same formula would not work because the object would move a much longer distance. The formula, in fact, is: "s = v x t + ⌀ x a x t^2", which is the same as before, plus a provision for the change in speed.

The way scientists write the factor, "a", is *dv/dt*, or the rate of change of "v". This is also called the *differential* of "v" with respect to "t". We can see that the speed "v" itself is the rate of change of distance "s", and then, by the same convention, v = ds/dt. The factor "a", which is dv/dt, then becomes d (ds/dt)/dt. The equation "s = v x t + ⌀ x a x t^2 ", is then called a *second degree differential equation*.

This kind of formulation is routine in physics and engineering and it enables an exact solution of most complex problems, from design of dams and bridges or computers to the launching of satellites.

Another kind of change of properties is when the property depends on more than one factor. Then there is more than one "rate of change" and the change in the value of the property is the total of some factor into each rate of change of the factors. This kind of equation is called a *partial differential equation*, and such equations are the way complex problems of the weather, radio waves or aerodynamics are solved.

Other than physical

The same method also helps solve problems in social and economic fields. The tendency of populations to relocate or switch consumption patterns, for instance, can depend on factors like climate, employment, availability of agricultural inputs or bank credit. It is possible to evaluate these factors and model the pressure to relocate in a mathematical form. Planners then have a powerful tool by which they can vary the factors that are within their control for the best benefit of all concerned.

The field of economic planning is a classic case of the use of mathematical models to regulate markets and currencies. In this case, the factors are large in number and have a complex behaviour and the analysis involves large data bases and powerful computers.

Another area where such modelling is used is in managing the flow of traffic, in town planning or the movement of wildlife populations in the drive for conservation. All responsible urban administrations have elaborate means to collect data of commuter behaviour and mathematical models are used to evaluate mass transit projects. The same methods are proving invaluable in managing environments to promote the survival of fragile wildlife and biodiversity resources.

George Tita identifies crime and criminal behaviour as one more area where these methods can be useful. "Illegal activity follows a discernible pattern," he says. "Criminals forage for opportunities to commit crimes, much like bees search for pollen or butterflies for nectar. Foraging patterns are predictable, whether you study human or insect behaviour."

Andrea Bertozzi

Jeffrey Brantingham

Data and study

Tita and colleagues made use of 10 years' data from Los Angeles police records and developed a model of the factors that influence criminality. Among other factors, an important one was the location of crime targets — like homes, cars and people on the street — and another was the probability of being caught, which depends on the level of policing, the kind of environment and also the past experience of offenders.

The crime records of LA showed two kinds of crime "hotspots" — one where there was a burst of crime in a locality, creating a kind of "crime wave", and another where there was a large rise of crime in an area that grew by attracting criminals from neighbouring locations. The model that Tita and colleagues have developed shows that stepping up policing in the first kind of crime rise would put a stop to the trend, but in the second kind policing only resulted in the centre moving to another, less policed area.

Modelling could thus enable enforcement agencies to clearly plan strategies to target crime systematically. "Crime is a function of a motivated offender, a suitable victim and the absence of governance," Tita says. "Criminals follow patterns just like everyone else in their daily lives."

The findings were published recently in the *Proceedings of the National Academy of Sciences*, and the team has received funding from the Office of Naval Research, USA, to see if it can shed light on insurgent groups in Iraq and Afghanistan.

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