

Social networks

Circles of friends

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What maths tells us about us

ALBERT EINSTEIN once remarked that common sense is the collection of prejudices someone has acquired by the age of 18. As such, it can be positively misleading as a guide to physicists studying fundamental particles or the structure of the universe. Instead, such researchers rely on mathematics. When it comes to studying human interactions, though, the reverse might be expected to be true—that common sense has everything to do with it, and mathematics nothing. But that turns out not to be the case. For one branch of the study of social networks seeks to model how people interact by using a type of maths known as graph theory.

The graphs of graph theory consist of sets of points (“nodes”) and the lines between those points (“links”). A link, in turn, can be directed (one node points to another) or undirected (two linked nodes have equal status). It sounds simple, and it is. Nevertheless, building on that framework, and understanding, among other things, whether some nodes tend to have many more links than others, and whether “cycles” of linked nodes are common in a graph, can allow graph theorists to say powerful things about, say, a telephone network or the internet. The question facing those studying social networks is: can the tools of graph theory also be used to reveal things about human behaviour that common sense does not?

Some mathematicians believe they certainly can. Jonathan Farley, a researcher at the Massachusetts Institute of Technology, is one of them. He helped to organise a workshop held on September 28th and 29th at Rutgers University, in New Jersey, which focused on the applications of graph theory to homeland defence and computer security. Dr Farley gave a talk at the workshop about using the theory to model networks of terrorists. In particular, he is interested in trying to work out whether or not the chain of command in a terrorist network has been disrupted by a particular action.

Nefarious networking

To do this, he models terrorist networks using a type of graph called an ordered set. This can be used to represent hierarchies. Dr Farley believes that if fed data on the number of members of a network who have been apprehended, an ordered-set model can give the authorities an estimate of the probability that the network has been disrupted. As Dr Farley is the first to admit, his model is rudimentary. Nonetheless, he believes it gives a better estimate than naive intuition would—and he has enough confidence in this belief to have founded a company that will sell analyses based on such techniques.

Although studying terrorist networks sounds a sure way to win grant money, it might eventually run into the sand simply because of the difficulty of gathering relevant data about real terrorist networks. Indeed that, to a lesser extent, can be a problem for any study of a human network. People change their behaviour under scrutiny, and lie on questionnaires. One group of researchers has thus

decided to cross the species barrier and test its models on another highly social mammal, the dolphin. No questionnaires are involved, and dolphins seem to worry about human observers about as much as humans would worry about an observant pet.

David Lusseau, of the University of Aberdeen, in Scotland, and Mark Newman, of the University of Michigan, in Ann Arbor, chose to look at the dolphins of Doubtful Sound, off the coast of New Zealand. Their results are about to be published in *Biology Letters*. Dr Newman's analysis of the animals' interactions suggested that what looked, superficially, like a single group was actually more akin to two groups held together by two "mutual friends". That prediction was borne out when Dr Lusseau saw the friends concerned leave the area. The Doubtful Sound dolphin community duly split in two. And when, after a period, the two mutual friends returned, the daughter groups rejoined precisely as the model predicted.

Dolphins, of course, are not people. And the Lusseau-Newman friendship model has still to be tested on humanity. Peter Bearman of Columbia University, however, is doing something similar, though looking not at friendships, but at sexual relationships. These have the virtue of being more clear-cut than friendships (did you sleep together or didn't you?) and thus what is or is not a link between nodes is unambiguous.

Earlier this summer Dr Bearman reported, in the *American Journal of Sociology*, an examination of high-school students' sexual activity and romantic relationships. When he plotted these as a graph, he found that it usually took many links (the record was 37, in a 500-pupil school) to get from one individual to another via an intervening chain of romantic entanglements—if, indeed, it were possible to make a connection at all.

That is in marked contrast to the sex lives of adults, where the sexual chains between people in a community tend to be rather short. It is also surprising, given the apparently cliquy nature of teenage life. Indeed, there were some specific surprises. One was that if two teenage couples broke up and one member of each couple started dating a member of the other couple, the two "dumpees" would almost certainly not form a relationship of their own. Put in terms of graph theory, there were no cycles of four—rings of four nodes with links connecting them.

Such results are of more than merely prurient interest. This sort of graph theory can yield insights into how sexually transmitted diseases spread—and how that spread might be stopped. The hopeful news Dr Bearman's work brings is that it should be easier to stop the spread of sexually transmitted diseases through a teenage-type graph than an adult one, since the spindly chains of connection between individuals can more easily be broken. Clearly the prejudices acquired by age 18 are not quite sufficient to explain the impact of lovers acquired afterwards.

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