Can math and science help solve crimes?

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Andrea Bertozzi, Martin Short and Jeffrey Brantingham

(PhysOrg.com) -- UCLA scientists working with Los Angeles police are using sophisticated mathematics to identify and analyze urban crime patterns.

UCLA's Jeffrey Brantingham works with the Los Angeles Police Department to analyze crime patterns. He also studies hunter-gatherers in Northern Tibet. If you tell him his research interests sound completely unrelated, he will quickly correct you.

"Criminal offenders are essentially hunter-gatherers; they forage for opportunities to commit crimes," said Brantingham, a UCLA associate professor of anthropology. "The behaviors that a hunter-gatherer uses to choose a wildebeest versus a gazelle are the same calculations a criminal uses to choose a Honda versus a Lexus."

Brantingham has been working for years with Andrea Bertozzi, a professor of mathematics and director of applied mathematics at UCLA, to apply sophisticated math to urban crime patterns. With their colleagues, they have built a mathematical model that allows them to analyze different types of criminal "hotspots" — areas where many crimes occur, at least for a time.

They believe their findings apply not only to Los Angeles but to cities worldwide. Their latest research will appear as the cover feature in the March 2 issue of Proceedings of the National Academy of Sciences (PNAS). Bertozzi will speak about the mathematics of crime at the annual meeting of the American Association for the Advancement of Science in San Diego.

The PNAS paper offers an explanation for when law enforcement officials can expect crime to be suppressed by intensified police actions and when crime might merely be displaced to other neighborhoods.

Crime hotspots come in at least two different types, Brantingham and Bertozzi report in PNAS, along with lead author Martin Short, a UCLA assistant adjunct professor of mathematics, and George Tita, an associate professor of criminology, law and society at UC Irvine. There are hotspots generated by small spikes in crime that grow ("super-critical hotspots") and hotspots where a large spike in crime pulls offenders into a central location ("subcritical hotspots"). The two types look the same from the surface, but they are not.

Policing actions directed at one type of hotspot will have a very different effect from actions directed at the other type.

"This finding is important because if you want the police to suppress the hotspot, you want to be able to later take them out and have the suppression remain," Bertozzi said. "And you can do that with only one of the two, in the subcritical case."

"Unless you are really looking for them, and our model says you should, you would not suspect these two types of hotspots," Brantingham said. "Just by mapping crime and looking at hotspots, you will not be able to know whether that is generated by a small variation in crime or by a big spike in crime.

"If you were to send police into a hotspot without knowing which kind it is, you would not be able to predict whether you will just cause displacement of crime — moving it somewhere else, which is what our model predicts if it's a hotspot generated by small fluctuations in crime — or whether you will actually reduce crime," he said. "Many people have argued that adding police to hotspots will just push crime somewhere else, but that seems not to be true, at least in certain cases. You get displacement in some cases, but not nearly as much as many people thought."

Drug hotspots and violent crime hotspots have been suppressed, and analysts up until now have not been able to explain why.

In their mathematical model, the scientists are able to predict how each type of hotspot will respond to increased policing, as well as when each type might occur, by a careful mathematical analysis involving what is known as bifurcation theory.

"Although this is an idealized model for which all parameters must be known precisely in advance in order to make predictions, we believe this is an important step in understanding why some crime hotspots are merely displaced while others are actually removed by hotspot policing," Bertozzi said.

Predicting crime and devising better crime-prevention strategies requires "a mechanistic explanation for how and why crime occurs where it does and when it does," Brantingham said. "We think we have made a big step in the direction of providing at least one core aspect of that explanation. We will refine it over time. You need to take these initial steps before you can develop new crime-fighting strategies."

Their model, Bertozzi said, "is nonlinear and develops complex patterns in space and time." These features, she noted, are well known in related models in other areas of science.

Bertozzi, Brantingham, Short and Tita have been studying crime patterns in Los Angeles using the last 10 years of data from the LAPD and have been able to identify violent crime hotspots, burglary hotspots and auto-theft hotspots, among others. They believe their analysis likely applies to a wide variety of crimes.

The research is federally funded by the National Science Foundation (www.nsf.gov) and the U.S. Department of Defense.

"We have a key to understanding real-world phenomena," Bertozzi said. "The key is the mathematics. With powerful mathematical tools, we can borrow methods that have been studied in great detail for other areas of science and engineering and figure out how to apply them to very different problems, such as crime patterns."

Will their research actually help police departments reduce crime?

"We're cautiously optimistic," Brantingham said. "Good science is done in small, incremental steps that can lead to big benefits in the long term. We are trying to understand the dynamics of crime and to make small but significant steps in helping our police partners come up with policing strategies that will help to reduce crime.

"We have to do what biologists and engineers have been doing for years, which is to try to understand the fundamental mechanics and dynamics of how a system works," he said. "Before you can make predictions about how the system will behave, you have to understand the fundamental dynamics. That's true with weather forecasting, where you run a climate simulation, and true with crime patterns."

The LAPD is at the world's forefront of knowing where crime is occurring and responding very quickly, Brantingham said.

"Can we actually push policing to look into the future and make a reasonable prediction about the near term when deciding how to allocate resources?" Brantingham asked. "This is the type of research that is necessary to make that a reality."

Why do criminals return to the scene of a crime, or at least the same general area?

"If my house is burglarized today, then it is more likely to be burglarized tomorrow as well," said Short, who has studied problems involving mathematical modeling and pattern formation. "There are good reasons for repeat victimization, from a criminal's point of view. They have already broken into your house once, so they know how to get in, and they already know what you have in your house. The data back this up.

"The 'near repeat effect' says not only is my house more likely to be burglarized again, but so are my neighbors' homes," Short added. "The burglar may be comfortable with that area. It may be near where he lives."

The scientists are also studying crime patterns with the mathematics used to forecast earthquakes and their aftershocks. "They are actually very similar," Bertozzi said.

In addition, they have started studying whether patterns of gang violence in Los Angeles are similar to insurgent killings in Iraq. Bertozzi will report preliminary data on this question at the AAAS meeting on Feb. 20.

"An insurgent who wants to place an improvised explosive device in a particular location will make the same kind of calculations that a car thief will use in choosing which car to steal," Brantingham said. "They want to go into areas where they feel comfortable, where they know the nooks and crannies. They want to be in an area where their activities will not appear suspicious. They also want to have a large impact.

"The same thing goes for a burglar trying to break into a house or a car thief or a guy looking for a bar fight," he said. "They want to go where they know they can go in and out without seeming too suspicious and where they can get the biggest bang for their buck. The mathematics underlying the insurgent activity and the criminal activity is very much the same. We're studying that now."

The researchers have funding from the U.S. Army Research Office's mathematics division to compare Iraq data and gang data.

They have also started a research project with the U.S. Office of Naval Research to provide mathematical algorithms that can help them extract information from diverse data sets.

Why is an anthropologist collaborating on a mathematical model to analyze human behavior?

"Many social scientists say human behavior and criminal behavior are too complex to be explained with a mathematical model," said Brantingham, who was trained as an archaeologist. "But it's not too complex. We're not trying to explain everything, but there are many aspects of human behavior that are easily understood in a formal mathematical structure. There are regularities to human behavior that we can understand mathematically."

"We're not asking whether a particular individual is going to commit a crime," Bertozzi said. "We ask whether a particular neighborhood will see an increase in crime."

It's a matter of group behavior, like studying traffic flow patterns, she said.

"Mathematical models and differential equations have been used in that field for decades," said Bertozzi, who had not worked with social scientists before working with Brantingham. She is interested in applying mathematics to address practical problems that affect peoples' lives.

"This is an exciting area of research," she said. "UCLA has one of the top applied mathematics programs in the country, and we are able to attract stellar graduate students, postdoctoral researchers and young faculty, such as Martin Short, who have made a huge impact in this research."

Bertozzi and Brantingham began working together after meeting through UCLA's Institute for Pure and Applied Mathematics.

"I knew if we were going to study crime problems, we needed excellent sources of data," Bertozzi said. "The fact that Jeff had the connection with LAPD and many interesting classes of problems to study intrigued me."

Bertozzi and Brantingham, along with George Tita and Lincoln Chayes, a UCLA professor of mathematics, wrote a proposal to the National Science Foundation to support the research, which was funded.

"A lot of what motivated me to look at crime initially was trying to take the approaches to understanding the physical world I learned in archaeology and applying it to contemporary problems such as crime," Brantingham said. "With George Tita and others, we reached out to the LAPD, and they have been very supportive of our work."

Provided by University of California Los Angeles

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