Mathematical model offers new strategies for urban burglary prevention

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As with most crime, the highest rates of burglary occur in urban communities since large metropolitan areas generally boast more concentrated wealth. Big cities also allow burglars to maintain anonymity and evade authority while offering ample opportunities for discreet disposal of stolen property. Burglars observe their target cities with the careful attention of urban planners, taking note of public spaces, roadways, building architecture, behavior patterns, and tenant schedules. Although law enforcement is making concerted efforts to address and prevent burglary, frequent offenses in major metropolises continue to unsettle city-dwellers.

Existing mathematical models typically examine burglaries in residential, suburban environments, where similarly-structured houses with predictable lattice alignments are hotspots for repeated criminal activity. Some are agent-based, others utilize differential equations, and still others account for the effect of police presence. These models suggest that residential burglars prefer revisiting previously-burgled houses—or those with similar architecture—because they are already familiar with layout, security features, and availability of goods. Thus, if a home or its neighboring residence is robbed, repeat or near-repeat victimization heightens that home's attractiveness. While this phenomenon—upon which most models are based—occurs throughout the world, it is much more common in suburban districts. Flexible models that include alternate patterns of victimization are especially desirable when considering urban burglary.

In an article publishing tomorrow in the *SIAM Journal on Applied Dynamical Systems*, Joan Saldaña, Maria Aguareles, Albert Avinyó, Marta Pellicer, and Jordi Ripoll present a nonlinear model of urban burglary dynamics that accounts for the deterring effect of police presence. Their model, which focuses on the Catalonia region of northern Spain, emphasizes timing of criminal activity rather than spatial spreading and location. "We first came in contact with the interesting field of mathematical modeling of burglaries during the 115th European Study Group with Industry," Aguareles said. "Pere Boqué, a mathematician who works as an analyst for the Catalan Police Department, set out the problem of anticipating a burglar's movements using predictive models in the same way that mathematical models for fluid dynamics allow meteorologists to predict the weather. We found the topic fascinating."

Their work is inspired by age-dependent population models, which study a population's evolution in time based on the physiological ages of its individuals. "Our model puts the emphasis on when—rather than where—the burglaries will take place and on the type of victimized houses, represented by their 'age,'" Avinyó said. A burglar's age is the amount of time since his most recent offense, while a house's age is the amount of time since it was last burglarized. The likelihood of robbery acts as a function of a burglar's age, and a house's susceptibility is a function of that house's age. When a burglar commits a crime, the ages of both the house and the burglar reset to zero. These details add a level of heterogeneity to the populations of houses and burglars.

"Our model focuses on the burglars' dynamics: their propensity to strike, their preference to act in groups, and different strategies to choose targets," Saldaña said. "All of these aspects are linked to the age of a burglar in our formulation. This allows us to implement different behavioral theories and use particular information obtained directly from offenders, like the so-called 'individual offending frequency' considered in criminology."

Because behavioral hypotheses related to repeat and near-repeat victimization limit a model's customizability, Saldaña et al. consider general functions for the recurrence rate (tendency of burglars to commit a crime) and victimization rate (rate at which houses are robbed). "Contrary to previous models where repeat and near-repeat victimization theories are widely considered, our model is compatible with different scenarios," Ripoll said. "Our age-structured model is a conceptually different approach in comparison with agent-based models where burglars are just seen as "particles" entering and leaving the system randomly. Less *a priori* assumptions are needed."

When preparing their model, the authors ignore demographic turnover and assume that both the total number of burglars and burgled houses remain constant, i.e., a closed population of burglars acts on a specific geographic area. They also presume that a house's victimization age directly correlates with its status as a desirable target. Other considerations include the belief that all burglars will eventually commit another robbery (as long as vulnerable targets still exist) and the possibility of burglars working together (co-offending). In the authors' model, a lower house vulnerability leads to a higher degree of co-offending. The aforementioned assumptions imply a predator-prey type relationship between burglars and vulnerable homes.

After establishing these fundamentals, Saldaña et al. modify their initial predator-prey system to account for active police response to criminal activity. "The organization of police resources and the allocation of police units is one of the main concerns of police departments," Ripoll said. "Nowadays many police departments tend to allocate police resources to help citizens feel secure. They ask police patrols to move randomly around different areas so that people develop a (sometimes false) sense of security. But this has long been observed to be quite an inefficient way to employ police resources."

Introduction of dynamic deterrence—in which police patrol reduces a burglar's intention to strike—means that the system's dynamics are dependent on history and prior offenses. As a consequence, each burglar must wait longer between burglaries due to heightened police presence in targeted areas. "The big question lies in the optimization of police resources," Ripoll continued. "This is why it is of great interest to understand the particular effect of police presence on burglar activity." When law enforcement more heavily considers recent crimes in its patrol efforts, the resulting deterrence factor lowers the frequency of burglaries and eventually reduces the recurrence rate.

Ultimately, Saldaña et al.'s nonlinear model of urban burglary offers more flexibility than traditional models based on spatio-temporal descriptions of criminal activity. "Our model is simple enough to provide some explicit formulae for relationships between different aspects of the dynamics," Pellicer said. "These can be contrasted with real data—for instance, the mean time between two consecutive burglaries of the same house and the mean time between two consecutive offenses committed by the same burglar—under different police strategies." When studying burglaries in a particular city, researchers must adjust their model's parameters and functions to correlate both qualitatively and quantitatively with real data.

Because this model is simpler than most previous models, it yields both numerical simulations and explicit results for further study. It also allows the authors to explore model adjustments, such as the introduction of space into the system via a meta-population approach or consideration of the burglars' physiological age or experience. Fundamentally, however, testing possible police configurations and strategies is of utmost importance. "Fitting the model with real data would definitely be relevant to police departments," Pellicer said. "We want to highlight the increase over the last few years in the association of mathematics with criminology to produce models that ultimately help with crime prevention."

More information: Saldaña, J., Aguareles, M., Avinyó, A., Pellicer, M., & Ripoll, J. (2018). An Age-Structured Population Approach for the Mathematical Modeling of Urban Burglaries. SIAM J. Appl. Dynam. Syst. To be published.

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