The Mathematical Structure of Terrorism

May 22 2006

The complex patterns of the natural world often turn out to be governed by relatively simple mathematical relationships. A seashell grows at a rate proportional to its size, resulting in a delicate spiral. The gossamer network of galaxies results from the simple interplay between cosmic expansion and the force of gravity over a wide range of scales. As our catalogue of natural phenomena has grown more complete, more and more scientists have begun to look for interesting patterns in human society.

The nature of war is a question of great interest to everyone, especially as the era of large-scale conflicts recedes into the past. The wars of today tend to be lopsided affairs, where guerilla forces, insurgent groups, and terrorists oppose incumbent governments. Instead of a few large-scale battles, this situation leads to an apparently random series of small-scale attacks against vulnerable targets of opportunity.

While affected governments collect records of past attacks, the random nature of such wars means that these data are of limited use in predicting future attacks. When classified according to their frequency and intensity, however, the events of any insurgent war appear to follow *a power law*. It should come as no surprise that weaker attacks are more common than stronger attacks, but a power law distribution makes a much more specific prediction. It turns out that if individual conflicts (for example, a terrorist attack or a guerilla raid) are classified according to the resulting number of fatalities n, then the number of such conflicts occurring in any given year is proportional to n raised to a constant power.

Let's look at a specific example. In the case of the Iraq war, we might ask how many conflicts causing ten casualties are expected to occur over a one-year period. According to the data, the answer is the average number of events per year times $10^{-2.3}$, or 0.005. If we instead ask how many events will cause twenty casualties, the answer is proportional to $20^{-2.3}$. Taking into account the entire history of any given war, one finds that the frequency of events on all scales can be predicted by exactly the same exponent.

Professor Neil Johnson of Oxford University has come up with a remarkable result regarding these power laws: for several different wars, the exponent has about the same value. Johnson studied the long-standing conflict in Colombia, the war in Iraq, the global rate of terrorist attacks in non-G7 countries, and the war in Afghanistan. In each case, the power law exponent that predicted the distribution of conflicts was close to the value –2.5.

What's more, in the case of Colombia and Iraq he was able to show that the exponent seemed to be *evolving* towards that value; Colombia from above, and Iraq from below. Does this hint at a simple underlying pattern driving the behavior of modern wars?

Johnson thinks so, and has even developed a model that predicts a power law distribution of casualties with the correct exponent. In his model, the insurgent force consists of a fixed number of attack units (a general term which may include equipment or even information, as well as people) which may group together to form larger units. Each unit on its own is assigned a 'strength' of one, meaning that a conflict involving that unit will result in one death. Coalitions of units pool their strength, and cause proportionally more deaths.

The key ingredient in this model is the evolution of groups over time. Terrorist organizations, for example, typically function in relatively small units. When an opportunity comes up that demands more resources, they may band together. When the authorities grow too close for comfort, on the other hand, they may split up. In time these competing pressures can create a stable arrangement of groups, with a fixed distribution of different sizes.

Johnson's model adopts a very simple dynamic to model this evolution. In any given time step, one group of attack units is randomly chosen. Each group's chance to be chosen is proportional to its size, but the many small groups still see much more activity than the few large groups. The group selected is given a small probability (1%) of disbanding into individual units; if it doesn't disband, then it joins up with another randomly chosen group.

These are the only rules of the model, and they turn out to work just fine. After the population is allowed to evolve for a long time, the result is a power law distribution of group sizes with an exponent of exactly –5/2. Since group size is proportional to attack strength, this distribution also predicts the frequency of attacks causing a given number of fatalities. It is also interesting that the result of this model depends only on the probability of fragmentation. As long as this probability is reasonably small, the distribution of attacking groups will settle into a steady state with a power law distribution.

Is this new 'Law of Terrorism' really universal? "Power law patterns will emerge within any modern asymmetric war being fought by loosely organized insurgent groups." Johnson speculates, "Although future wars will provide the ultimate test." Johnson's research continues with the analysis of data from other conflicts, such as Senegal, Indonesia, Israel, and Northern Ireland.

Citation: Neil Johnson et al. 2006, "Universal Patterns Underlying Ongoing Wars and Terrorism", http://xxx.lanl.gov/abs/physics/0605035

By Ben Mathiesen, Copyright 2006 PhysOrg.com