the Complexity of Conflict

BY DAN ROCKMORE

The PowerPoint slide shown to General Stanley McChrystal around the time he took charge of the conflict in Afghanistan depicted a mass of interests and threats, a *New York Times* article reported. It included topics such as "tribal governance," "infrastructure services and economy," and "military tactical strategies" among many others, all tied together with a chaotic web of arrows that looked as orderly as a bowl of spaghetti. The image could be described with two words: "It's complex," but five words offer more precision: "It's a complex adaptive system."

As a step toward understanding conflict as a complex system, in May 2010 SFI's Business Network and the New America Foundation (NAF) co-sponsored in Washington D.C. a one-day symposium, "Seeing Conflict in a New Light." That new light was the illumination that comes from bringing ideas of complexity science study to this notoriously opaque phenomenon.

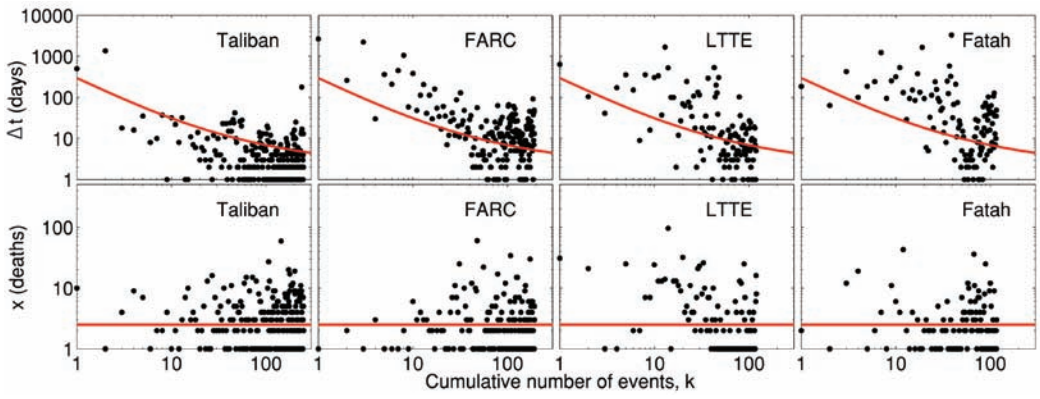
Conflict and Complex Systems—A Thumbnail History

The conjunction of complex systems and conflict is hardly a shotgun marriage. Conflict is a lens through which many complex systems phenomena can be seen. It occurs on the scale of cells, individuals, and

This sequence of events below was captured on video by Jessica Flack while she was collecting data on social dynamics at the Yerkes Regional Primate Research Center. It shows a fight erupting between an adult female pigtailed macaque and a juvenile. A second juvenile intervenes on behalf of the first. The female responds with aggression and then retreats. Many fights involve only two or three animals. However some can grow to include as many as thirty animals, consuming almost a third of the group.



bu Nidal Organization (ANO) Abu Sayyaf Group Al-Aqsa Martyrs Brigade Al-Shabaab Ansar al-Islam A
ist Party of the Philippines/New People's Army (CPP/NPA) Continuity Irish Republican Army Gama'a
esh (HUJI-B) Harakat ul-Mujahidin (HUM) Hizballah (Party of God) Islamic Jihad Group Islamic Mover
on (JI) Kahane Chai (Kach) Kata'ib Hizballah Kongra-Gel (KGK, formerly Kurdistan Workers' Party, PKK
elam (LTTE) Libyan Islamic Fighting Group (LIFG) Moroccan Islamic Combatant Group (GICM) Mujah



AARON CLAUSET

This graph illustrates the attacks of the four most prolific terrorist groups in the world. The upper cells show the delay in days between consecutive attacks, while the lower show the severity of attacks, both as a function of the cumulative number of attacks. The trend lines show the model, illustrating that terrorist groups tend to accelerate their attacks according to a power-law function as they gain experience, but later attacks are no more deadly than earlier ones.

societies, over microseconds and millennia, in environments ranging from the intercellular battles that accompany the body's fights against disease and aging, through the struggle for resources in ecosystems or societies, and to the gamesmanship of the marketplace, boardroom, or playing field. The ways one engages in conflict can be examined from various perspectives, such as through game theory and optimization (making the most—with respect to some property or criteria—of a complicated situation), which are cornerstones of complex systems analysis.

The first appearances of what one might consider a complex systems approach to the study of conflict can be found in the work of Lewis Fry Richardson (1881—1953). Richardson was a polymath and, in retrospect, something of a one-man Santa Fe Institute. His early work was in fluid dynamics and meteorology, taking on the notoriously difficult problem of numerical weather prediction, and as such, butting heads with the infamous "butterfly effect." This phenomenon—in which a small cause in a complex system can have a large effect elsewhere in the system—he encountered decades before the birth of modern nonlinear dynamics and chaos theory.

His belief in the power of science and mathematics coupled with his Quaker upbringing and experiences of World War I eventually led him to turn his data-driven attentions to a quantitative study of conflict, with the goal of bringing a dispassionate and thus (in his mind) necessarily irrefutable voice to the analysis of societal and international violence. His first attempt at this gave us the eponymous Richardson equations, a pair of coupled linear differential equations relating the rates and current levels of arms expenditures between two mutually antagonistic nations. Richardson saw arms



Armed Islamic Group (GIA) Asbat al-Ansar Aum Shinrikyo Basque Fatherland and Liberty (ETA) Comm
al-Islamiyya (Islamic Group) HAMAS (Islamic Resistance Movement) Harakat ul-Jihad-i-Islami/Bangla-
ment of Uzbekistan (IMU) Jaish-e-Mohammed (JEM) (Army of Mohammed) Jemaah Islamiya organiza-
, KADEK) Lashkar-e Tayyiba (LT) (Army of the Righteous) Lashkar i Jhangvi Liberation Tigers of Tamil
edin-e Khalq Organization (MEK) National Liberation Army (ELN) Palestine Liberation Front (PLF)

expenditures as a measurable proxy for bellicosity, and his work shows that even under fairly simple assumptions, arms races can have a variety of dynamics.

Richardson's later work attempted to understand the influence of various national characteristics on the proclivity to violence. In trying to incorporate real (as opposed to numerical) boundary conditions—such as the length of a country's borders—into the mix, he was led to the discovery of fractal dimension, yet another statistical foundation of complex systems.

Of all this, Richardson's *magnum opus* in conflict analysis was *Statistics of Deadly Quarrels*—a compendium and analysis of data measuring the violence in society from roughly 1820 to 1950, ranging in scale from homicides to world wars, but excluding natural disasters. In conflict, as in many phenomena, while the individual events appear "random," statistical structure emerges at the large scale. Careful analysis of the numbers led to the discovery of what some now call Richardson's Law of conflict, which is that the distribution of casualties has the form of a power law. Among their interesting features, power law distributions possess a "heavy tail," meaning that events far out in the distribution still occur with some significant probability or frequency. For example, we've all experienced of late the heavy tail of stock price movements.

Viewing Violence as Business

Aaron Clauset (University of Colorado, Boulder, and a former SFI Omidyar Fellow) uses Richardson's Law as a jumping-off point for his research of terrorism. Clauset's first work on the subject of conflict was with Maxwell Young in the Department of Computer Science at the University of New Mexico. The research resulted in a Richardson-like analysis of the terrorism casualties as collected in the National Memorial Institute for the Prevention of Terrorism database. It showed the power law statistical regularity in the casualty data.

Power laws are ubiquitous in the statistical analysis of many complex systems phenomena, exhibiting a simple structural relationship in the observed distribution of events—in this case that the probability an attack has a given number of casualties is approximately a fixed power of the number of casualties. Trying to understand models of conflict that create this kind of distribution can lead to understandings about the mechanisms of conflict.

While this structure is interesting, it is only a first step, for it suggests the much more important question of "What is the source of this regularity?" Clauset and Young show that this structure is consistent with a model of "competition" between the insurgents and the nation-state in which the magnitude of the attack as well as the probability of intervention by the nation-state are proportional to the time taken to prepare the attack.

At the May meeting Clauset spoke about new work with Kristian Gleditsch, a researcher at the University of Essex and the Centre for the Study of Civil War in Oslo, Norway. The two find that the timing between attacks by various organized violent actors decreases according to



alestinian Islamic Jihad (PIJ) Popular Front for the Liberation of Palestine (PFLF) PFLP-General Comma
-Jihad fi Bilad al-Rafidayn (QJBR) (al-Qaida in Iraq) (formerly Jama'at al-Tawhid wa'al-Jihad, JTJ, al-Zarq
the Arabian Peninsula (AQAP) al-Qaida in the Islamic Maghreb (formerly GSPC) Real IRA Revolution
FARC) Revolutionary Organization 17 November Revolutionary People's Liberation Party/Front (DHKP
ath (Sendero Luminoso, SL) United Self-Defense Forces of Colombia (AUC) Harakat-ul Jihad Islami (H

a power law in the group's experience, while the size of the attack is independent of their age. This focus on the maturity of the organization with attendant hypotheses regarding its functional capabilities has interesting analogies in the business world with respect to the inception, growth, and success of companies. In this framework the terrorist groups are cast as start-up companies whose primary product is political violence, "valued" in the currency of casualties. Most striking is their finding that the "development curves" (relating organizational age to time between events as well as number of casualties) bear a striking similarity to the production curves in manufacturing relating production costs with cumulative number of items produced.

Calculating Probabilities of Conflict

SFI Professor Jessica Flack brings a biological and evolutionary approach to the problem, taking the point of view that a broader perspective is necessary for the articulation of more general, even universal, principles of conflict. In addition, the investigation of conflict in settings outside the human realm can allow for the rigorous testing of hypotheses regarding the nature of conflict.

Flack has for many years been studying primate societies, in particular analyzing a macaque colony at the Yerkes National Primate Research Center, a part of Emory University located outside of Atlanta. Flack sees the macaque collective as a model system for the study of many aspects of social dynamics, including conflict. As opposed to the coarse kinds of casualty data that usually form the basis of conflict studies, the constant close surveillance of the primate microsociety provides scientists with an extraordinarily detailed and highly resolved dataset of interactions and outcomes. Flack and her colleagues have been able to examine this data to produce a general analytic framework for the study of conflict.

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Flack's recent work, in collaboration with SFI Professor and Faculty Chair David Krakauer and Omidyar Fellow Simon DeDeo, applies the tools of *inductive* game theory (a methodology created by them) to "discover" strategies of conflict in the macaque society (48 adult macaques) from time series that encode their behaviors over several observation periods. It is precisely in this ability to extract strategies as opposed to positing them *a priori* that distinguishes (in part) inductive game theory from classical, or *deductive,* game theory.

The time series of conflict dynamics abstracts the macaque behavior into the basic data of who participated in conflict, their roles in the conflict, and the start and stop times of the conflicts. The focus on participants



and (PFLP-GC) Tanzim Qa'idat
awi Network) al-Qa'ida al-Qa'ida
ary Armed Forces of Colombia
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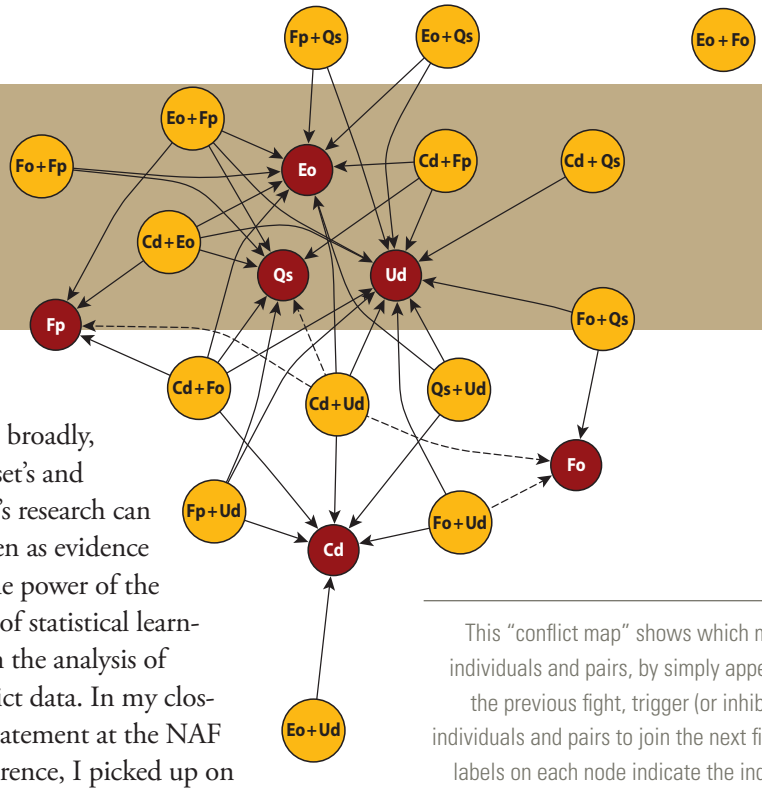
HUJI) Tehrik-e Taliban Pakistan

and timing yields some surprising conclusions mainly related to the role of memory in conflict. The data enables the calculation of the (conditional) probabilities that any given subset of actors engages in a next conflict, given that some other specified subset engaged most recently in a conflict. For example, the figure on the right shows significant pairwise effects with an arrow from individual A to individual B if the presence of A in a conflict is a "significant" indicator for the presence of B in the next conflict. This probabilistic approach enables Flack and her colleagues to separate out the significant (and sometimes overwhelming) role of memory in conflict from various "externalities" such as resource competition. This has obvious relevance for many of today's most violent conflicts. The results are enabled by the creation of an elegant formal language for specifying the dynamics of conflict. This produces a rigorous framework for the testing of hypotheses about conflict generally (e.g., replace macaque with insurgent group) that can be used to articulate strategic paradigms in human conflicts.

CHART: JESSICA FLACK; RE-CREATION BY JAN UNDERWOOD



This "conflict map" shows which macaque individuals and pairs, by simply appearing in the previous fight, trigger (or inhibit) other individuals and pairs to join the next fight. The labels on each node indicate the individuals or pairs in the macaque group to whom the node corresponds. Red nodes are frequently involved in fights. A solid line between nodes indicates the relation is excitatory, while a dashed line indicates the relation is inhibitory. The direction of the arrow indicates who triggers or inhibits whom.

More broadly, Clauset's and Flack's research can be seen as evidence for the power of the tools of statistical learning in the analysis of conflict data. In my closing statement at the NAF conference, I picked up on this theme, noting that statistical learning is the modern instantiation of what is often referred to as "pattern recognition"—that is, the automatic (i.e., computer-guided) discovery of structure in data. I discussed the various ways these methods have been applied in a variety of areas, including textual and behavioral analysis, and how they might then find further use in conflict. When turned on its head, these tools also enable the discovery of anomalous behavior in the data stream, akin to the search for the canary in the coal mine that might presage a violent action.

Richardson is quoted as seeing war as primarily "chaos," though partially "restricted by geography and modified by infectiousness." In the work of Clauset and Flack and others in the SFI community, we see that these complex systems references are more than metaphor. ◀

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